HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES
KAPOSVÁR CAMPUS
INSTITUTE OF PHYSIOLOGY AND ANIMAL NUTRITION

Influence of Ensiling on the Ruminal Degradability of Winter Cereal Mixtures

AUTHOR
Boluwatife Olagunju

Animal Nutrition and Feed Safety MSc

SUPERVISOR
Dr. Róbert Tóthi PhD
Associate professor, Department of Farm Animal Nutrition

HEAD OF DEPARTMENT
Dr. Veronika Halas PhD
Associate professor, Department of Farm Animal Nutrition

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Table of Contents

INTRODUCTION

High-quality forage is crucial for every lactating dairy ration. Corn silage and alfalfa haylage are a major portion of a dairy ration in many countries, especially during lactation. Corn silage is an economical source of energy that is highly palatable for dairy cows and it has a high productivity per hectare. These characteristics make corn silage an important forage source, especially in countries with marginal availability of land for growing feed. Alfalfa haylage/silage can be a valuable complement to corn silage in dairy rations. This complementarity of corn silage:alfalfa haylage mixtures includes agronomical, nutritional, and economical purposes. A significant portion of that complementarity relates to the efficiency of the utilization of nitrogen on the farm. Alfalfa silage complements corn silage in dairy diets because alfalfa is high in protein, particularly rumen degradable protein. Alfalfa also complements corn in crop rotation, since it can fix nitrogen and can provide other desirable characteristics such as reducing soil erosion and improving soil tilth. However, in recent years, agricultural production and productivity have been strongly affected by climate change which has had a negative impact on maize plant production for forage. Therefore, the need for producers and policy makers to find alternative forage sources is pivotal.

The negative impact of climate change on the agricultural productivity of forage plants is more severely felt in tropical areas like my home country, Nigeria. Therefore, the dairy sector of the EU, Hungary (country of study), Nigeria (home country), and the World at large, will be reviewed and compared in the literature review. These alternative forage sources are not used to entirely replace already existing forage varieties but rather used to complement them. The different alternative cereal types of combination can still give good fiber before the heading stages of the plants. According to the available literature data, forage from winter cereal mixtures grown and ensiled alone has outstanding yields, feed value, and ruminal degradability. For example, the degradability of barley and winter oat in the rumen is high; therefore, it improves the dry matter intake. Winter triticale also has a high yield potential. On the other hand, Italian ryegrass both in its fresh and preserved form is frequently used as forage for dairy cows and is known for its high energy value and highly digestible fiber. Winter cereals can provide feed earlier than annual ryegrass (early autumn) because they are generally more adaptable to early sowing due to higher tolerance of dry conditions. Cereals are also better suited to single-cut silage-making, whereas annual ryegrass requires multiple cuts or grazing to be fully utilized. The nutritive value of winter cereals is similar to ryegrass in the tillering stage but declines during the later stages of growth. Maximum yields of cereals can only be obtained by single-cut silage-making (with or without being grazed once during the early stages). However, the losses from harvest to feeding out cereal silage can considerably increase the cost per kilogram of feed consumed by the cows compared to fully grazed annual ryegrass particularly for whole crop silage cut at the late milk-soft dough stage.

1. LITERATURE REVIEW

1.1. Dairy Sector of Europe and Hungary

1.1.1. Dairy Sector of Europe

After the vegetable and horticultural plant sector, and before the cereal sector, the EU dairy sector is the second biggest agricultural sector in the EU, which represents more than 12% of the EU's total agricultural output (Bas–Defossez et al., 2019). In 2016, European dairy farmers produced 168.3 million tonnes of milk; among this, 97% was cows' milk while 3% was milk from ewes, goats, and buffalo. The EU had the largest production of milk in absolute values and relative to population size among G20 members in 2016 (Marie-Laure, 2018). Farm herd size, yields and the types of farming performed vary widely across Europe. It ranges from free-range farming in Alpine areas to large, specialized dairy farming in the northwest and central Europe. Alpine areas are specifically important for milk production in the EU, accounting for around 10 per cent of overall EU milk production. This ranges as high as > 60 per cent production in Austria, Finland, and Slovenia. In the EU, organic milk production holds only a small share of the total milk production which was around 3 per cent in 2016 (Bas–Defossez et al., 2019). All 28 Member States produce milk but the main producers of cow milk are France, Germany, the Netherlands, the United Kingdom, Italy, Poland, and Ireland, which together account for three quarters of total EU production. The remaining 21 Member States produces just a quarter of EU production (Marie-Laure, 2018). Most of the milk produced is delivered to dairy companies for further processing, the rest are normally used in other ways on the farms (either consumed, processed, directly marketed, or used as feed). In 2017, around 156 million tonnes of cows' milk were delivered to EU dairy companies. There are around 12,000 milk processing plants employing 300 000 people in the EU. The dairy sector is predominantly organized in cooperatives, which are in charge of 55 % of the market share. These cooperatives can either be as large as a world-leading multinational companies or they can be as small as SMEs or micro-enterprises (Marie-Laure, 2018).

The milk delivered to dairy companies is processed into fresh products (drinking milk and other fresh products such as yoghurts, cream, fermented milks, etc.) and manufactured products: cheese, butter, milk powder, whey, etc. The production of butter and cream generates skimmed milk as a by-product, which in turn is sold as drinking milk, used to make cheese and other products, or converted into powder milk (Marie-Laure, 2018).

1.1.1.1. General evolution of the EU dairy sector

From 1983 to 2013, the number of farms having dairy cows decreased by 81 % (-1.2 million dairy farms) in the initial ten EU Member States. This reduction was sharper than that registered for all types of farms (-55 %). Over the past 30 years, four out of every five dairy farms disappeared. Alongside this, a gradual decline in the number of dairy farmers in the EU also occurred (-6 % a year on average). However, the proportion of specialized dairy farms has increased in the EU. Average herd sizes have shown an increasing tendency, as well as milk yields, mainly because of genetic improvements and feed efficiency. In addition to this consolidation trend, dairy farmers work more closely together through cooperatives. The overall level of milk production has remained generally stable due to the quota regime. Larger volume production of added-value products, especially for exports, is evidence of the greater market orientation of the milk sector in recent years. For example, cheese production increased by 26% between 2003 and 2013, and cheese exports rose by 69% (Marie-Laure, 2018).

1.1.1.2. EU dairy farming sector structure

The distribution of milk production across the EU is not even. Particularly, great differences exist between the EU15 and EU13 on one hand and the EU-N and EU-S on the other (Ihle et al., 2017). Over half of the specialized dairy farms in the EU are large or very large farms. As mentioned already, there is a wide range of dairy farms in the EU: those in the EU-15 are much bigger on average and have higher yields than those in the EU-13. This diversity in the structures of dairy farms across the EU is linked to the differences in natural potential alongside the social economic and regulatory context. Many specialized dairy farms are situated mainly in the north-western Member States of the EU. By economic size, the largest specialized dairy farms in the EU can be found in the UK, the East of Germany, Slovakia, and Denmark. The number of dairy cows in the EU in 2015 was 23.4 million which were all unevenly distributed across the EU (Table 1). Germany had the highest number of dairy cows in 2017 with 4.2 million, making up 18% of the total EU-28 dairy cow population. France ranked second with 3.6 million units (15%). At the other end of the scale, Malta having around 6,000 dairy cows, remained the smallest milk producer in 2017. Dutch regions have mainly high levels of milk production relative to their size. In 2016, 85% of total EU milk production (168 million tonnes) was produced in the EU-15.

Holstein Friesian is the most common dairy cattle breed in the EU. Other breeds include Montbéliarde, Normande, Simmental, Swiss Brown, Ayrshire and Jersey to name just a few (Marie-Laure, 2018).

Table 1. The structure of milk production in the EU in 2015 (Rico et al., 2017)

Region	**Dairy Cows**		**Milk Yield**		**Milk Production**		**Milk Deliveries**		**Share of Produced Milk Delivered to Dairies**
	Number (1000)	**Share**	**Amount (kg/cow)**	**In relation to the EU average**	**Amount (1000 t)**	**Share**	**Amount (1000 t)**	**Share**	
EU	23,364	100%	6,859	100%	160,258	100%	152,189	100%	95%
EU15	18,146	78%	7,356	107%	133,491	83%	130,777	86%	98%
EU13	5,218	22%	5,130	75%	26,767	17%	21,412	14%	80%
EU-N	14,907	64%	7,175	105%	106,966	67%	103,737	68%	97%
EU-S	8,457	36%	6,302	92%	53,292	33%	48,452	32%	91%

In the EU-15, yields per dairy cow are 43 % higher than in the EU-13. Significant contrasts exist between EU countries and regions. At national level, the highest annual yields can be found in Sweden, Denmark, Finland, Estonia, and Portugal (between 8 278 and 9 361 kg per head) and the lowest in Romania, Croatia and Bulgaria (from 3 343 to 4 566 kg per head). At regional level, Lombardia, Italy had the highest milk yield per dairy cow in 2016 which was 9 870 kg per head. In the EU-15, specialized milk farms have a milk yield of 7 264 kg/cow for an average herd of 55 cows, while the average milk yield is 5 036 kg/cow for an average herd of nine cows in the EU-13 (Marie-Laure, 2018).

1.1.1.3. Specific types of milk production in the EU

Organic production

Approximately 3% of the milk produced in the EU in 2016 was organic. In countries like Denmark, Sweden, Latvia Latvia and Austria, organic milk accounts for 10% or more of total milk production. However, in Ireland, Spain, and Poland, it represents less than 0.5%. On organic farms, cow yields are on average 3% lower than on conventional farms. Several farm conversions have occurred in response to the dairy crisis, since organic milk can be sold at a higher price and consumers are also turning strongly towards organic products (Marie-Laure, 2018).

Mountain production

Dairy farming is a key activity in the EU's mountain regions, which is among the category of disadvantaged areas. In its resolution (2013) on maintaining milk production in mountain areas, the EU Parliament found that, in total, mountain milk was responsible for around 10% of milk produced in the EU. In Austria, Finland, and Slovenia it accounts for two-thirds of production and three quarters of producers and is also very significant in another 10 countries. Mountain dairy farming is mostly small-scale and extensive. It aid in the sustainable development of mountain areas through delivering public goods (helping to maintain landscapes and biodiversity) and by having a positive effect on the local economy. It supports the local economy by helping to keep rural communities alive, mostly through synergies with tourism. In local regions having natural handicaps, the production, transport, and collection costs are generally higher compared to lowland dairy farming (Marie-Laure, 2018).

1.1.2. Hungarian Dairy Sector

The number of the Hungarian dairy cows has declined from 630 thousand to 311 thousand animals over the past two decades. In the beginning, the declining number of cow livestock was not notable in the amount of raw cow milk production, which was around 1.9-2.1 million tonnes. However, the increase in specific cow yield was not able to compensate the national milk production descent. Therefore, the Hungarian raw milk production has been on a continuous decline (Blaskó et al., 2012). Positively, since 2009, milk production began to increase continuously, and it has now reached 1.924 million tonnes per year (HCSO, 2019). Production in respect to quantity was the highest in 1988 when the Hungarian annual milk production was 2.95 million tonnes which coincided with a record number of dairy cows [2.5 million] (Kovács and Szűcs, 2020). On the other hand, the number of dairy cows in Hungary has been dramatically decreasing until 2010, but annual milk production seems to have stagnated at around 1.8 million tonnes, implying an increasing yield per dairy cow indicator. The growth of milk yield production per dairy cow is very notable ranging from 5000 litres/head to 8000 litres/head on average from 1990 to 2017 (Kovács and Szűcs, 2020). The specific yield per cow was able to compensate this decline in cow number, and therefore, the volume of raw milk production remained stable. This correlation is down to the fact that due to Hungary's EU accession, most of the rural dairy companies stopped functioning and small producers with only a few dairy cows and low yields were forced to stop production. Thus, the average Hungarian yield per cow started to increase (Blaskó et al., 2012).

1.2. Nigerian Dairy Sector

Having an estimated 20 million cattle including 2.35 million cows used for dairy production, Nigeria has the 4th largest cattle population in Africa (FAOSTAT, 2013). There is also evidence of cattle originally from Cameroon, Niger, Chad and Burkina Faso, in Nigerian markets. (Sahel, 2019). The Nigerian dairy industry is not fully developed, as well as those in other West African countries. There is therefore a need to develop the industry because demand for milk and dairy products is high and as a result of the increasing population and increasing knowledge on nutrition. Also, there must be trained personnel to collect, process, and distribute the milk while also having a continuous supply of milk to sustain the demand of the markets (FUNAAB, 2011).

More than 90% of total annual milk production is from cattle in low-input low-yielding pastoral systems and traded in informal value chains (CSIRO, 2022). The consumption level of dairy products is low and estimated at 2kg per capita annually while cattle production system is largely smallholders' with little or no purchase input. Cattle productivity is low due to high reproductive wastage, low calving rate as well as low milk yield per lactation (FUNAAB, 2011). The main dairy products in the Nigerian market are made from reconstituted milk powder from Europe, South Africa, United States of America, New Zealand, etc., which vary in taste, flavor and nutrient profile compared with fresh milk. Majority of indigenous dairy farmers lack basic education, which preclude them from making contribution on policy issues affecting their production. Moreover, urbanization and expansion in arable farming activities deny them access to grazing lands. Even with grazing reserves being developed by

Government, the infrastructural resources such as water, pastures, health facilities and market facilities are limited, diminish accessibility by majority of producers (FUNAAB, 2011).

1.2.1. Dairy Schemes in Nigeria

The dairy schemes in Nigeria can be classified into three categories, which are: those whose herds are settled, those whose herds are unsettled and those without herds.

1.2.1.1. Dairy schemes whose herds are settled

Settled dairy schemes are those dairy farms with establishments that are highly organized and permanent on one site. Most dairy farms in this category are government owned. This dairy schemes are the urban dairies, dairies on schools of Agriculture, universities, and vocational institutions (FUNAAB, 2011).

1.2.1.2. Dairy schemes whose herds are unsettled

These are schemes which do not maintain a farm for rearing cows. Under these schemes, a dairy is built with milk collection centre in central areas to the kraal. Milk in this category is purchased from the herds men who are predominantly Fulanis and Shuwa Arab tribesmen. For acceptability, the milk is subjected to physical and chemical tests. The milk is then transported to the dairy processing centre some kilometers away where it is pasteurized and sold as liquid milk, cheese, butter and yoghurt. Schemes that follow this pattern include the Ilorin milk pilot project. The Dairy is built in Ilorin and the milk is collected from a distance of 10km radius. Ilorin milk pilot project was equipped with modern equipment donated by the UNICEF. Pasteurized milk, butter and yoghurt are made from the milk that is purchased (FUNAAB, 2011).

1.2.1.3. Dairies without herds

This is the scheme without herds also known as the ‘Plants’. These are dairies that depend upon importation for their raw materials (FUNAAB, 2011).

1.2.2. Nigeria Cattle Population

Majority of cattle in Nigeria are indigenous breeds used primarily for meat and savings as well as milk production. Exotic breeds such as Holstein Friesian, Brown Swiss, Jersey and their crosses are common in more intensive, specialised dairy systems (CSIRO, 2022).
The prominent percentage of the cattle population of Nigeria is in the extensive production system (Table 2). This is due to the fact that nomadic farming is the largest portion of dairy cattle production in Nigeria.

Table 2. Nigeria cattle population by production system (FAO 2018)

Production system	Number (heads)	% of total population
Extensive	15,111,309	82.1
Semi-intensive	3,089,804	16.8
Intensive	203,548	1.1

1.2.3. Types of Dairy Production Systems in Nigeria

1.2.3.1. Extensive or traditional system

In the extensive system of dairy production in Nigeria, the producers are generally scattered among rural communities at far distances from the urban centers. The stock used consists of a collection of cows sometimes goats and sheep. The cows are not selected for high milk production or any of the other characteristics derivable in a good dairy animal. Milking is not carried out at regular intervals and very often there is no record for milk produced by each cow. There are no cultivated pastures on which to feed the animals. The animals rely on grazing on the open range grounds with the change of seasons. In most cases, this development results in a very low level of production. The milk produced is not usually processed and the system requires thousands of milking cows to satisfy the requirement of the market (FUNAAB, 2011).

- Large herds of indigenous cattle in pastoral & agro-pastoral areas in northern Nigeria. Cattle graze on natural pastures, communal land, and crop residues.
- Milk and dairy products are consumed by producer households and sold through local community markets.

1.2.3.2. Intensive/improved/specialised system

The intensive system of dairy production in Nigeria involves the use of dairy animals specialized for milk production. This involves the investment of considerable capital. The size of the dairy herd can vary from 50-100 cows for small scale operations and up to 500-1000 cows for medium size operator. The large-scale operation has more than 1000 cows. The animal used for this operation are high-yielding European type of breeds e.g., Friesian. In some of urban dairies in Nigeria, crosses of European breeds with indigenous cattle, selected indigenous cow are used in urban dairies in Nigeria. Breeding records are kept and selection for high milk yield is intensively carried out. The milk is regularly tested for quality and AI is used to improve the milk producing ability of the animal. The animals are fed regularly on cultivated pastures usually green soiled or zero-grazed. They are also supplemented with concentrates usually rationed according to production. The animals are housed, and milking is usually done in a dairy parlor under hygienic conditions. There is a considerable degree of mechanization in most of the operations. The animals are subjected to regular veterinary inspection to prevent and cure diseases. Under this system of production, the farmer is concerned with making as much profit as possible (FUNAAB, 2011).

- About 80% of the commercial dairy farms are in the central region.
- Herd size ranges from 50 to 1000 heads.
- Cattle are kept in sheds/indoors and fed in a ‘cut and carry’ system based on cultivated pastures and supplementary feed.
- Most milk is sold into formal value chains.

1.2.3.3. Semi-intensive system

The semi-intensive system of dairy production in Nigeria involves the integration of both the intensive and extensive system of dairy production. In this production system, animals rely on both grazing and can be supplemented with concentrates usually rationed according to production and season of the year.

1.2.4. Value Chains & Market Systems

The Nigerian dairy sector is largely fragmented, unproductive, and inefficient despite its size. Though smallholder dairy households (i.e. pastoralists) produce most of the raw milk in Nigeria, the end market is controlled by large multinationals that use imported milk in over 97% of products consumed (Sahel, 2019). Pastoralists account for 95% of milk production in

Nigeria. Commercial farmers account for only 5% of local milk production. Milk and dairy products produced by pastoralists are consumed by pastoralist households and/or marketed locally through informal value chains. Milk produced by pastoralists is rarely processed before sale and consumption. Milk may be processed into several local products which are mainly cheese and yogurt products. Milk from commercial dairy farms is traded through formal value chains in urban and peri-urban markets. The average milk consumption in Nigeria is 20 to 25 litres per capita per year (CSIRO, 2022).

1.2.5. Milk Yields

According to CSIRO (2022), the gross production value of cow milk in Nigeria in the year 2016 was US $73 million. Below are the milk yields of cows in the two main dairy farming systems in Nigeria:

- Average milk yield in traditional low-input systems is 6 l/cow/day.
- Average yield of pure breed (Friesian) in a specialised commercial system is 30 l/cow/day.

The difference in yields is due to a range of factors including cattle breed, nutrition, animal health and farm management (CSIRO, 2022).

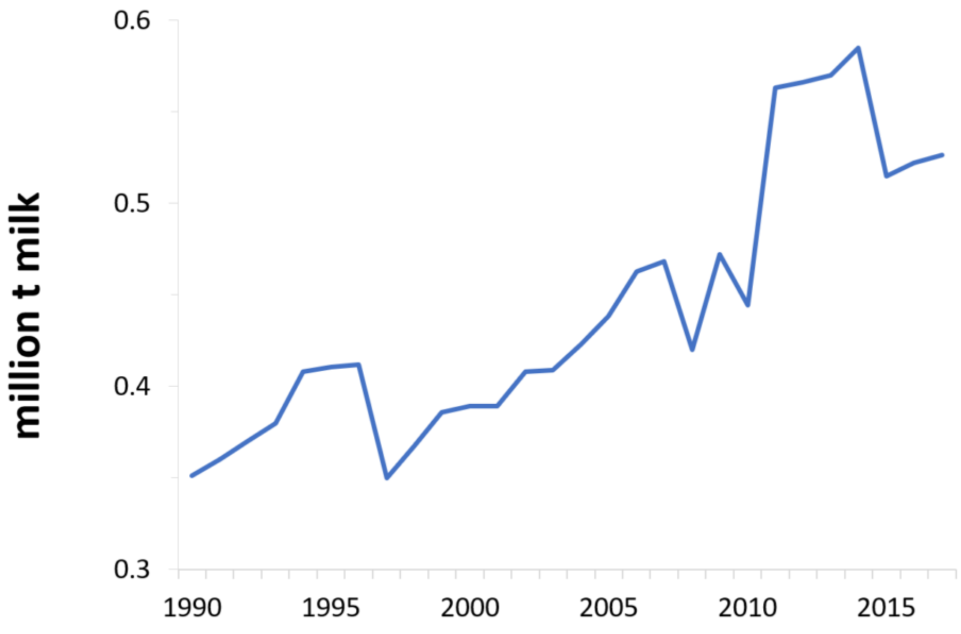

Figure 1. National milk production from cattle in Nigeria (FAOstat).

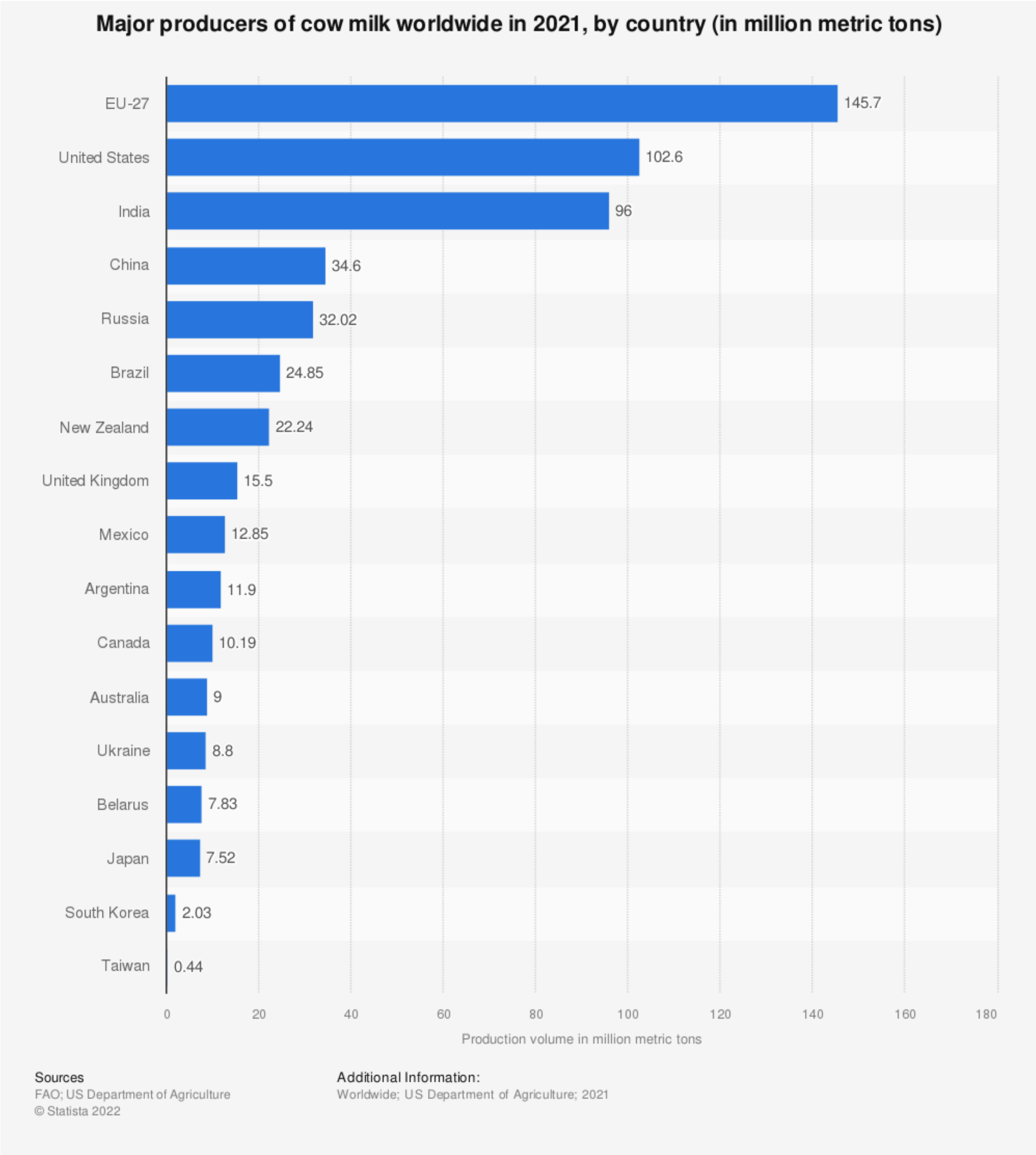

Figure 2. Leading producers of cow milk worldwide by country (Shahbandeh, 2022)

Even though the milk production yield of Nigeria has been on a gradual rise since the past decades, this rise has been slow compared to that of other top milk producing countries of the world. Comparing the graphical trend according to Figure 1 and the data in Table 1 and Figure 2, it is clear that Nigeria is lagging behind in terms of its milk production compared to the production in other EU countries and compared to the world at large. The slow transition from extensive dairy production system to a more intensive system is the main cause of this low yield in the milk production of Nigeria. With that being a problem, coupled with the negative impact of climate change to the production of good forage plant sources, many potential producers are discouraged about going into the dairy industry. The knowledge of being able to use ensiled cereal mixtures to complement the already exist forages like maize silage, will be useful for farmers/producers in Nigeria and other tropical countries. With the potential benefits of these ensiled cereal mixtures compared to other convention high-cost forage plants, this can reduce the cost of production for the farmers/producers while still maintaining high milk yields in their dairy cows.

1.2.6. Issues Affecting Milk Production in Nigeria

According to CSIRO (2022), the major problems with milk production in Nigeria, both in the farm scale and value chains are:

- ❖ Farm scale
    - Seasonal feed shortages (natural grasses, crop residues).
    - Decreased land area available for grazing.
    - Cost and variable quality of purchased concentrate feeds.
    - Genetic potential of cattle breeds currently used.
    - Inappropriate breeds for local conditions.
    - Cost and access to artificial insemination services.
    - Diseases that cause mortality or affect reproduction.
- ❖ Dairy value chains, markets & processing

  Seasonality of milk production makes it hard for producers to engage in formal value chains.

1.3. Benefits and Characteristics of Corn Silage for High Producing Dairy Cow

Corn silage is a low-cost source of energy in the form of starch and fibre (Kolver et al., 2001). Plant maturity at harvest plays a big part in many of the nutrient characteristics of corn silage. The dry matter (DM) content of the plant can be used to indicate maturity, with more mature plants having a higher DM content. Although the fibre and lignin content of the stover increases with age, the increased grain fill with age means that fibre levels of the whole plant are reduced as the plant matures (Bal et al., 1997). These changes occur in concert with an increase in energy content until DM content is approximately 35%, a dramatic increase in starch content, and a small reduction in protein. When corn silage of different maturities was fed as part of a total mixed ration to dairy cows, milk yield was highest for the silage with a DM content of 35% (Bal et al. 1997). These changes in nutrient content and resultant yield of energy per ha are the basis for the recommendation to harvest at between 30–35% DM (Kolver et al., 2001).

1.4. Alternative Forage Sources

As mentioned already, there are many alternative forage sources for feeding dairy cows especially winter cereal-based ones.. These types of feed may increase in importance due to their high yields, and high degree of flexibility in rotations, and the potential to adjust rapidly to water supply and diversity of wheat, triticale, rye, oats, and barley - are widely adapted, highly versatile forages used for making silage.

1.4.1. Winter wheat

Wang et al. (2013) reported that switching from corn silage to whole crop wheat increased cow milk production. Winter wheat is considered as a species with the high rate of degradation in rumen compared to other small grain cereals, which is associated with increased risks of health problems in cattle (Pozdíšek and Vaculová, 2008). Many papers devoted to the study of wheat grain quality document differences between cultivars that are caused by environmental effects (location in combination with temperatures and precipitation) and agronomic management (level of N fertilizer, preceding crop), method of grain processing and treatment, and lastly, by combination with other feeds and supplements in animal diets (Owens et al., 1986; Stokes, 1997; Rowe et al., 1999; Black, 2001; Tománková and Homolka, 2004; De Campaneere et al., 2005). The crude protein level of whole-crop wheat silage in the milk-ripe stage was 1% to 2% higher than whole corn silage, but NDF and ADF were almost identical. Moss and Givens (2002) found that the rumen degradable starch disappearance, which is an important characteristic of the nutritive value of wheat for ruminants, is influenced by the year of harvest, site of growth, agronomic management, and cultivar. A study of two different wheat samples by Liyi et al. (2021) found that wheat starches were mainly rapidly degradable (65.5 and 72.4%). It was also reported to have the highest effective digestibility (ED) of DM (86.8 and 85.9%) with a relatively high fast-degradable DM fraction (53.7 and 49.5%, respectively) compared to other cereals like oat, triticale, sorghum and barley.

1.4.2. Winter barley

Kaulbars and King (2004) found that when harvested at early-dough stage, barley has a lower dry matter yield (3.9 t/ha) than triticale (5.3 t/ha) or oats (4.1 t/ha) (Baron et al., 2000). However, it has a better fodder quality than oats or triticale collected at the same maturity level. Barley has a higher DM digestibility than triticale or oats at all growth stages (from boot to soft dough stage). Baron et al. (1992) reported that barley used for silage is generally harvested in western Canada at mid-dough stage to balance its DM output and nutritional quality. In comparison to corn silage collected at two-thirds milk line. Besides, barley silage harvested at mid-dough stage had higher CP (13.3 vs 9.6%) and lower starch content (25.9 vs 30.5%) on [% DM] basis. Growing beef steers on barley silage-based backgrounding diets exhibited higher DMI (7.1 vs 6.9 kg/day), ADG (1.43 vs 1.26 kg), and G:F (0.20 vs 0.18) than steers fed corn silage-based diets, according to these researchers. Furthermore, Liyi et al. (2021) found that the DM degradability of ground barley was relatively high (82.4%), while its fast-degradable portion was low (39.6%). Also, the degradability of barley was significantly ($p < 0.05$) lower than that of wheat, while the degradation of starch was faster than that of DM and CP. The protein degradability of barley was found to be 82.3%.

1.4.3. Winter triticale

According to McCartney and Vaage (1994) triticale harvested at early-dough for silage showed higher ADF and NDF concentration than barley and oat ensiled at soft-dough or milk. Growing beef heifers fed triticale silage showed lower DMI and ADG than those fed oat or barley silage, according to the same authors. The reported reason for lower DMI in the heifers fed triticale silage was poor palatability. According to (Koch and Paisley, 2002) and (Mut et al., 2006), triticale produces at least 20% more hay than wheat and has better fodder quality than wheat and rye. Liyi et al. (2021) also found that the CP degradability of triticale is 75.2%. Due to its high protein production and amino acid balance, triticale is a good source of feed for dairy cows.

1.4.4. Winter oat

McCartney and Vaage (1994) reported that in comparison to barley and triticale, oat has a lower CP content and DM degradability. Growing beef heifers fed oat silage had similar DMI and lower ADG than those fed barley silage. Oats harvested at milky, and barley harvested at soft-dough for silage had identical ADF and NDF concentrations). Furthermore, Liyi et al. (2021) found that oats had a higher rapidly degradable DM fraction compared to other winter cereals like barley, wheat, triticale, etc., but did not lead to high degradability. Also, around 94.8% of the starch in oats were rapidly degradable in the rumen. Moreover, oats had the highest CP degradability of 93.7% compared to other cereals like winter wheat, triticale, sorghum and barley.

1.4.5. Winter cereal mixtures

Not many studies have been done on the ruminal degradability of winter cereal mixtures and thereby, there are not many literature data available in this area. Cereals such as oats, wheat and barley are primary cereal fodders grown in rainfed conditions around the world for cattle nourishment. These cereals are pleasant, succulent, and nutritious fodders with adequate amount of carbohydrate content, but they are protein deficient, which is critical for animal health and productivity. When fed as pure fodders, either of legumes or cereals, the consumption of fodder is lower than when supplied as cereal legume combinations, according to the literature. When fed with other cold-season legume crops including berseem, lucerne (alfalfa), white clover, red clover, and vetch, oats (Vicia sativa) make a great mix. Barley, is also a winter-hardy crop that could be a promising addition to annual legume-cereal combinations for forages and hay (Karadağ and Büyükburç, 2003). Lithourgidis et al. (2006) reported that the growth rate of individual species in mixtures, as well as fodder yield and quality, may be affected by mixing vetch with oats, barley, and wheat. Cereals can help encourage climbing vetches, increase light interception, and make mechanical harvesting easier. Incorporating legumes with cereals could be critical for the nutritional value of the forage mixture as well as subsequent soil health. To provide a climbing frame for the legume and to boost the amount of feed output, oats, barley, wheat, and triticale are added (Roberts et al., 1989). Barley-vetch and barley-grass pea rotations yielded greater dry matter and crude protein than barley-barley or barley-fallow rotations, according to some previous researchers (Nadeem et al., 2010). According to Papastylianou (1990), Cereal species planted in conjunction with legume mixture components may have an impact on the yield and quality of fodder generated by the combinations. Vetch and wheat together provided larger seed and protein yields than a single cereal (Jensen, 1996), since they did not compete for nutrient in the soil. Common vetch with oats has been documented as the most suitable cereal- legume mixture for increased fodder yield (Caballero and Goicoechea, 1986; Thompson et al., 1990) whereas in some other studies barley (Roberts et al., 1989) and wheat (Thompson et al., 1992) proved as the most suitable cereals for fodder mixtures.

1.5. *In sacco* Method Estimation of Dietary Nutrient Degradability in the Rumen

The most widely used method to estimate the rumen degradation of dietary components in feedstuffs is the *in situ* or *in sacco* method. This method is based on rumen incubation of substrate (feed) in nylon or dacron bags followed by rinsing and analysis of the residue. Small pores in the bag allow microbes to enter the bag whilst a variable portion of the feed is retained in the bag. The results are used to estimate the ruminal effective degradation (ED) that is used in several protein evaluation systems. The suspension of feed materials into the rumen (e.g., in situ bag technique, in-sacco technique, artificial fiber bag technique) allows for proper interaction of the test feed with the ruminal environment. This has proven over the years to be the best method to simulate the rumen environment within a given feeding regimen (pH, temperature, buffer substrate, enzymes), even though in the ruminal environment, the feed is not subjected to the total ruminal experience (mastication, rumination, and passage). This technique has been used for several years and is the basis for predicting digestion in several feeding systems (Chalupa, 1975; NRC, 1985; Waldo et al. 1984).

However, the increased popularity of this method has also subjected it to extensive evaluation and criticism about the many inherent factors that influence digestion (e.g., bag pore size, sample size, sample particle size). Various aspects of the in-sacco technique interact in nature and can influence the interpretation of *in situ* results (Nocek, 1988).

The degradation curve shown in Figure 3 were obtained by retaining the samples in the rumen (by containment in a nylon bag). Normally, forage materials can leave the rumen once its particle size has been reduced by degradation and rumination.

Many concentrate feeds and supplements already have particle sizes small enough to leave the rumen without further size reduction. Thus, the degradation actually achieved within the rumen (effective degradability) will be dependent on how long the food remains within the rumen i.e., the retention time (Lock, 2015).

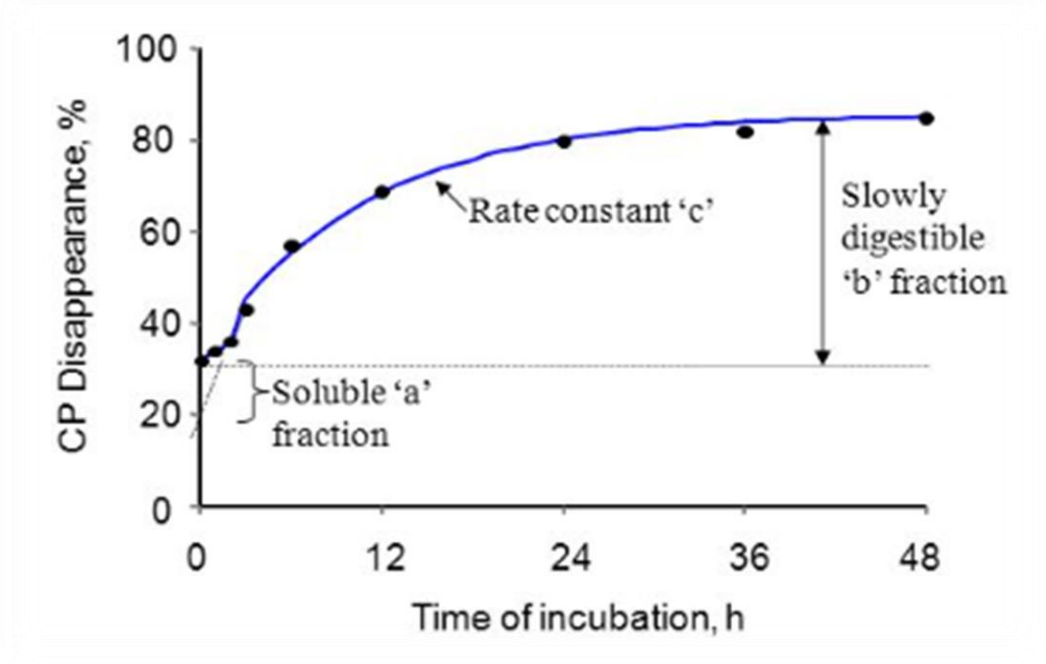

Figure 3. Graphical illustration of the in-sacco ruminal degradability of silage nutrients (Lock, 2015).

Graph parameters

- Time of incubation (h): This is the total amount of time feed samples/mixtures is exposed to the ruminal environment for degradation by the rumen microbes.
- CP Disappearance (%): This represents the rate/speed at which CP or other nutrient component of the tested feeds exits the rumen according to the rumen incubation time.
- Soluble 'a' fraction: This is the nutrient component of a tested feed sample which is rapidly degradable consisting mainly of starch and other portions of the feed sample that digest rapidly.
- Slowly digestible 'b' fraction: This is the nutrient component of a tested feed sample which degrades slowly in the rumen and comprises mainly of the fiber part of the feed like ADF or NDF.
- Rate constant 'c': This is the time taken between the degradation of various fractions of the feed sample.

According to Nocek (1988) the following are some important parameters which can affect in-sacco degradability of nutrients and there is a potential for interaction between these parameters which must also be considered.

1.5.1. Bag Porosity

The appropriate porosity is a compromise between limiting influx of rumen contents not associated with the test feed and allowing influx of microbial populations to degrade the test feed while at the same time limiting the efflux of undegradable feed particles. Inherent in the technique is the soluble and "mechanical" loss of feed particles from the bag prior to ruminal incubation. The actual digestibility of this fraction is not quantifiable through the in-situ technique but is often assumed to be associated with the rapidly degradable and readily available fraction, which may or may not be precise (Mahadevan et al., 1980 and Nocek et al. 1983). The soluble and mechanical particle loss can account for a considerable proportion of nutrients, particularly of N in fermented forages (Nocek and Grant, 1987). Several researchers (Lindberg and Knutsson, 1981; Nocek, 1985; Nocek and Grant, 1987) have opted to use a preincubation wash to quantitate and remove this questionable fraction as well as to prewet the sample to mimic salivation. Pre-ruminal incubation (15 rain in 39°C water; 1 L/250 mg feed N) of soybean meal (SGM, 2-mm grind) resulted in 15 and 27% loss of N and DM from bags, ranging in pore size from 6 to 59 μm (no difference in pore size on DM or N washout). However, as the pore size increased to 80 and 102 μm, N and DM washout increased by 30 and 14%, respectively. There was an increased loss of DM as bag porosity increased from 10 to 36 μm after a 6-h soak with agitation. Loss of DM was only 2.6% for SBM with the 36-gm porosity; however, barley increased from 11 to 25% as pore size increased (Lindberg and Knutsson 1981). Weakley et al. (1983) showed lower disappearance of DM and N from SBM and distillers grain from 5-μm pore bags compared with that from 52-μm dacron bags, regardless of ruminal residence time, and indicated much of the difference was established in the first hour. Except for barley, Lindberg and Varvikko (1982) reported that DM disappearance was greatest from bags with 36-μm pores followed by those with 20-μm and 10-μm pores. Uden and Van Soest (1984) showed cell wall digestion of timothy increased with increasing pore size (20, 37, and 53 μm). Pore sizes of 6 and 20 μm significantly reduced N digestion rate of SBM compared with larger sizes (Murphy and Nicoletti, 1984). Pore sizes ranging from 40 to 102 μm were similar and higher in estimated rumen N availability than 6 or 20 μm and compared more favorably to *in vivo* estimates. Meyers and Mackie (1983) compared total culturable counts in rumen ingesta and in residue samples within nylon bags of different pore sizes (5 to 53 μm) containing alfalfa hay. Total culturable counts were < 10% in 5-μm and 10-μm bags and about 60% of the amount in rumen digesta in 53-μm bags. Those workers indicated 30 to 53-μm bag pore size is optimal in relation to counts of protozoa and bacteria. Uden and Van Soest (1984) observed influx of very fine material in 20-μm bags. These workers also indicated the increase in cell wall digestion with increased pore size could not be totally explained by mechanical losses alone. Some reports (Nocek and Hall, 1984; Uden and Van Soest, 1974) observed gas accumulation in bags of small pore size (< 10 μm). Researchers (Lindberg and Knutsson, 1981; Lindberg and Varvikko, 1982) indicated that if feed material remains in the rumen for extended times (48 h), the amount of undigested residue is not significantly affected by pore size. Although extent of digestion is important, the rate at which nutrients disappear from the bag in relation to the rate of ruminal passage dictate true extent of ruminal availability. The limits of bag porosity are difficult to ascertain and are most likely dependent on sample particle size and nature and type of feedstuff being investigated. A porosity of 40 to 60 μm appears to be a good compromise concerning microbial and content influx and digested material efflux. Bag material should have a definable pore size and material type (Nocek, 1988).

1.5.2. Particle Size

Because the bags used in in situ digestion studies are preferably not masticated or ruminated, microbial fermentation and detrition by ruminal activity are the only means by which particle reduction occurs. There is much controversy as to the degree of particle breakdown associated with microbial digestion (Moseley and Jones, 1984; Murphy and Nicoletti, 1984; Nocek and Kohn, 1988; Pearce and Moir, 1964). It is debatable as to whether prepared material for in situ study should mimic that which is fed or mimic that after mastication and presentation to the rumen. Generally, longer and coarser materials are associated with slower rates of digestion and greater variation. However, finely ground materials are subject to greater mechanical losses from the bags (resulting sometimes in unrealistically rapid rates of digestion) but variation is more controlled (Nocek, 1988). Weakely et al. (1977) indicated DM and M degradation of SBM was less with coarse (2000 μm) than with fine particle size (520 μm). Ehle et al. (1982) showed rates of N digestion for several feed ingredients were not affected by particle size within feed sample (1180, 600, 300, 150 μm; 70-μm pore size; 20-g sample). In a subsequent study, Weakley et al. (1983) further showed that pulverization (50 to 150 μm) of commercially processed forms of SBM or distillers grains increased DM and N disappearance. Nocek (1985) found no difference in DM or N digestion rates for SBM that was unground or ground (1, 2, or 5 mm) and incubated in bags of 59-μm pore size. Very little information is available to compare particle sizes of whole grain and fibrous by-product type ingredients for in situ experimentation. Nocek (1987) demonstrated that grinding (5 mm) various corn grain forms increased rates of N, DM, and non-N DM disappearance with ruminal incubation times up to 100 h (59-µm pore size) compared with the as-fed form. In addition, considerably more water-soluble and filterable material exited bags of ground corn prior to ruminal incubation compared with the as-fed form. There was also a tendency for a greater disappearance of nutrients in the first 24 h of incubation. Grinding also changes the relative rates of which N and nonprotein DM are digested. Grinding, particularly of forages, increases surface area per unit weight of sample and the surface area accessible for microbial attachment. This generally results in increased digestion rate. In addition, smaller, more uniform particles result in a less variable sample placed in the bag. Grinding alfalfa and timothy hay (Nocek and Kohn, 1988) markedly reduced variation in DM digestion and increased rates of DM and NDF digestion compared to field chopped material. Grinds of less than 1 mm have little effect on digestion rate. Work by Van Keuren and Heiniman (1962) demonstrated no difference in DM disappearance for forages ground at .28, .42, and .84 mm. However, decreasing particle size to < .6 mm may also cause clumping of the sample, thus decreasing digestion rate (Figroid et al., 1972). Solaiman et al. (1982) showed shorter lag times and less undigestible cell wall for alfalfa and orchard grass ground at 1 mm than at 8mm.

1.5.3. Sample Size to Bag Surface Ratio

The optimum sample size is that which provides enough residue at the end of extended rumen incubation for chemical analysis without over filling the bag so as to delay bacterial attachment, increase lag time, and underestimate digestion rates. Sample size to bag surface ratio also provides a barometer of the appropriate sample size for among laboratory comparisons (Nocek, 1988). Uden and Van Soest (1974) showed CW digestibility decreased from 54 to 3 8% when sample size increased from 6.5 to 50 mg/cm^2. Likewise, Van Keuren and Heinemann (1962) showed a decrease in DM digestion, especially at 24 and 48 h of ruminal incubation, for alfalfa, orchardgrass, and sudangrass. Bullis et al. (1967) also reported sample size influenced DM disappearance. For forages, Van Hellen and Ellis (Van Hellen and Ellis, 1977) recommends 10 mg/cm^2, whereas Uden and Van Soest (1984) recommend not more than 6 to 7 mg/cm^2. Figroid et al. (1972) showed no difference in DM disappearance of sorghum grain when sample size increased from 2 to 10 g (1.0 mm grind, 10.2 x 17.8-cm bags) at 3 and 6 h of ruminal incubation. With narrower bags, DM disappearance of barley was reduced with 14 g of sample; however, no further reduction in DM disappearance was noticed with 18 g of sample. Varga and Hoover

(1983) compared two bag sizes (9 × 17 vs. 13 × 21 cm) and sample weights (2.5 and 5.0 g) to evaluate DM disappearance of various ingredient and forage sources. Dry matter disappearance was depressed by 3 and 8 percentage units for sample weight to bag surface area ratios of 4.6 vs. 8.2 and 9.2 vs. 16.3 mg/cm^2. These authors indicated after 30 h of ruminal incubation, 5-g sample sizes did not yield enough residue to conduct DM and NDF analysis. When 8 g of sample were included in the larger bag (14.6 mg/cm^2), results were similar to the 5-g sample (9.2 mg/cm^2). Reports for N digestion of concentrate-type ingredients have used ratios of 3.5 mg/cm^2 (Crawford et al. 1978) and 4.2 mg/cm^2 (Stern and Satter 1984). Nocek (1985) compared four different ratios with different sample grinds using 59-µm bags to evaluate N disappearance of SBM. Mean N disappearance rates were significantly higher for ratios of 2.5 compared to 12.6, 25.3, and 37.9 mg/cm^2. Although not significant, rates for 25.3 and 37.9 mg/cm^2 were 16% lower than for 12.6 mg/cm^2. Estimates of ruminal available protein indicated the 12.6 mg/cm^2 ratio was nearest to reported in vivo estimates. As sample size increases in relation to bag surface, feed tends to become more compacted with the microenvironment of the bag, thus restricting rumen fluid flow and contact with feed particles and thereby reducing digestion rate, especially in the initial periods of incubation. Large sample to surface area ratios are especially critical for concentrate type ingredients, because they generally have greater density with more potential for particles to coalescence than the more fibrous matrix of forage. Range in sample size to bag surface area ratio of 10 to 20 gm/cm^2 should be utilized for most forage and concentrate type ingredients. The exact amount of sample (and bag size) to be incubated will depend on the potential extent of ruminal digestion of a given ingredient or forage in relation to extended ruminal incubation times and the number of chemical analyses that one desired to be conducted on the residue (Nocek, 1988).

1.5.4. Dietary Effects

Diet is the major factor determining quantity and types of microbes and therefore the rate and extent of digestion of dietary nutrients. For example, feeding of high concentrate diets (highly fermentable carbohydrate) ferments soluble sugars and starch more rapidly, which reduces ruminal pH and causes an ultimate shift to a more amylolytic-type population at the expense of cellulolytic and protozoa (Lindberg, 1981; Mackie and Gilchrist, 1979; Nocek and Polan 1984). Because feed samples placed in nylon bags suspended in the rumen are in intimate contact with ruminal microbes, an influence on rate and extent of digestion of that sample would seem likely (Nocek, 1988). Lindberg (1981) fed cows basal diets ranging from 30%

forage to all forage (grass-hay or ammoniated-barley straw with cracked oats as the concentrate) to evaluate DM and CW digestibility for a variety of feedstuffs. Dry matter disappearance from hay, fish meal, beet pulp, and SBM was significantly affected by forage to concentrate ratio; however, several other feeds were not influenced. Digestibility of CW decreased for all forage type ingredients as concentrate increased, particularly between 12 and 48 h. The rate and extent of cell wall digestion of different forages varied with forage type as starch increased from 0 to 80% in the diet.

The digestion rate of alfalfa decreased with starch addition; however, coastal bermuda grass, fescue, and orchard grass were relatively unaffected. Other factors, such as fiber crystallinity, site availability for surface attachment, and physical structure may also influence rate and extent of digestion (Mertens and Loften 1980). Weakley et al. (1983) fed cows diets containing either 25, 40, 60, or 80% alfalfa hay to evaluate N digestion of SBM. Diets containing 25% hay yielded the lowest and 80% hay the highest extent of N digestion. They postulated that in addition to microbial factors, physical factors associated with hay and forage diets may contribute to increased digestion; those include less clogging of bag pores from bacterial slime associated with high concentrate diets, abrasive action between bag surface and fibrous material of high forage diets, and differential pressures exerted on feed samples associated with mixing action from ruminal contractions. Reports according to (Ganev et al., 1979; Lindberg, 1981) indicate an association between N and CW digestion for many feed ingredients and that N components in natural feeds are protected from degradation by fibrous structure. Therefore, if high concentrate diets depress fiber digestion, it then follows that N digestion would also be depressed. Bacterial contamination of residues can influence this interpretation. The N and energy concentration of the ration fed to the cannulated cow has shown to have a variable effect on in situ digestion results, DeFaria and Huber (1984) evaluated in situ DM digestion of corn silage, alfalfa silage, and grass hay in diets containing three different protein (8.1, 11.3, and 13.3%) and three different energy concentrations (ADF = 39, 29.9, and 21%). Neither protein nor energy had a significant effect on DM digestibility for any forages; however, specific sampling time by forage interactions were noted. Vik-Mo and Lindberg (1985) indicated that, in general, N and DM disappearance for several feeds was higher in high protein diets. Others (Nocek and Grant, 1987) demonstrated NH_3 concentration in the rumen had no effect on N or DM disappearance of SBM.

2. GOAL OF THE STUDY

The objective of the experiment was to evaluate the *in sacco* ruminal degradability of two different mixtures of winter-cereals-based silages. The *in sacco* ruminal degradability experimental method is a well-accepted method of studying the ruminal degradability of forages in ruminants. Therefore, the *in sacco* ruminal degradability experimental method was used for this study.

Even though the ruminal degradability of sole winter cereal forages is well-known, there are not many available data about the ruminal degradability of forage cereal mixtures. In this study, two different winter cereal forage mixtures were evaluated individually using the *in sacco* ruminal degradability experimental method to determine how much they can be degraded in the rumen of dairy cows.

3. MATERIALS AND METHODS

3.1. Experimental Site

The trial was carried out on a medium-scale farm (Kaposvár University, Hungary – 46°22' N 17°48' E, 153 m altitude (GeoDatos, 2020). Two different winter cereal mixtures (commercial products, *Agroteam S.p.a.*, Torrimpietre (RM), Via di Granaretto, 26, 00054 Italy) were studied:

- Missuri (30% of two cultivars of winter oat + 40% of two cultivars of winter triticale + 10% of winter barley + 20% of winter wheat).
- Texas (50% of two cultivars of winter triticale + 10% of winter barley + 40% of winter wheat).

The experimental field allotted 3 hectares to each mixture. Deep loosening and disc plus cylinder cultivation were executed as stubble tillage. 351 kg/ha artificial fertilizer (NPK: 16:16:16) was applied before sowing. Seedbed was prepared by Kongskilde VibroFlex 7400 cultivator (lifted). The forage mixtures were sown on 29th September (75 kg seed/ha) with depth of 3 cm with John Deere 740 A type seed drill. Plant protection treatment was not applied during the growing period. The annual precipitation was 425 mm (World weather online/Kaposvár monthly climate average).

3.2. Harvesting and Conservation

Cutting was carried out at the heading stage of triticale based on the existing extended BBCH-scale (Meier, 2001) on 4th May. The growth stages of development of the plants at harvesting was determined according to scale BBCH (acronym for Biologische Bundesanstalt, Bundessortenamt and CHemical industry). Accordingly, therefore oat was BBCH 51; triticale was BBCH 53; winter wheat was BBCH 52; winter barley: BBCH 58. After cutting, the fresh forage mixtures were wilted to 35% DM (24h) without any movement on the windrow to have a well fermented haylage. During wilting the forage mixtures did not ted since tedding leaves the stems oriented at random while parallel stems will allow baling denser. Then the wilted forage with a capacity of 578-675 kg was wrapped by a John Deere 7300 fitted with cross wrap bale wrappers, without additives, in plastic using 6 mils of plastic and 50% overlap and 50% to 55% stretch. Then bales were stored in Hungarian University of Agriculture and Life Sciences dairy farms on a level concrete floor and the bales were arranged stacked to reduce sunlight exposure to save plastic and reduce sweating.

3.3. Ruminal Degradability Study and Chemical Analysis

After the 90 days of fermentation, the ensiled mixtures were subjected to ruminal degradability study. The ruminal degradability trial was carried out with three multiparous non-lactating Holstein-Friesian dairy cows (600±35 kg body weight) previously surgically fitted (ethical permission number - SOI/31/01044 – 3/2017) with a ruminal cannula (10 cm id., Bar-Diamond Inc., Parma, Idaho, USA) at the experimental dairy farm of Hungarian University of Agriculture and Life Sciences. Cows were fed total mixed ration (TMR) formulated according to the dairy nutrient requirement and feeding standard (NRC, 2001) in equal portions at 8:00 and 14:00 on *ad libitum* basis. The baseline diet [9.12 kg dry matter intake (DMI)/day; 6.32 MJ NEl /kg DM; 14.40% CP, 39.06% NDF, 23.66% ADF, and 35.71% non-fibrous carbohydrate (NFC)] consisted of 5.50 kg/day of corn silage, 3.50 kg/day of alfalfa haylage, 3.50 kg/day of vetch-triticale haylage, 3 kg/day of concentrate, 1 kg/day of grass hay and 0.75 kg/day of liquid molasses. The cows consumed the daily allotted TMR with no daily feed refusal throughout the course of the experimental period. Water was available *ad libitum*. Rumen incubations were carried out according to Herrera-Saldana et al. (1990). Nylon bags of 5×10 cm with pore size of 53 µm (Ankom, USA) filled with sample weight of 5.00 g (on air dry matter basis) was incubated for 0, 2, 4, 8, 16, 24, 48 and 72 h incubation times. In each incubation, 60 bags per sample were used (5 bags × 4 replications per sample × 3 cows). The 0 h samples were not placed in the rumen, but they were soaked and rinsed as described below. Removed bags were placed in cold tap water immediately after removal from the rumen, and they were washed by hand until the water was clear. After washing, the bags were dried in a forced air oven at 60 °C for 48 h, air equilibrated and weighed. Residues from the bags were pooled within time and finely ground by mortar and pestle to pass through a 1-mm screen and retained in sealed containers to determine DM, CP, NDF and ADF. Feeds were analyzed for nitrogen according to Kjeldahl (AOAC, 2006), and thereafter, CP was determined by the total nitrogen (N) × 6.25. The NDF and ADF contents were residual portions after rinsing according to Van Soest et al. (1991).

3.4. Calculations and Statistical Analysis

Residues from the nylon bags at each incubation time were analysed for DM, CP, NDF and ADF as described above. Ruminal nutrient disappearance data were used to determine nutrient degradation parameters using the equation (Ørskov and McDonald, 1979):

$$P = a + b\,(1 - e^{-ct}),$$

where P is the DM, CP, NDF or ADF disappearance (%) at time t, a is the soluble fraction (%), b is the potentially degradable fraction (%), and c is the rate of degradation of the b fraction (%/h).

Effective degradability (ED) of DM, CP, NDF and ADF was then calculated according to the equation (Ørskov and McDonald, 1979):

$$ED = a + ((b \times c)/(k + c)),$$

where k is the rumen outflow rate assumed to be 1, 5 and 8%/h and a, b, and c are as described above.

According to this experiment, the parameters for determining rumen degradability of DM, CP, NDF and ADF were as follows.

Soluble fraction (% of DM): This is the nutrient component of the cereal mixtures which is rapidly degradable in the rumen consisting mainly of starch and other portions of the feed sample that digest rapidly.

Potentially degradable fraction (% of DM): This is the nutrient component of the cereal mixtures which includes the slowly degradable and some degradable portions which might or might not be potentially degradable by the rumen microbes depending on certain factors like NDF and ADF.

Degradation rate (%/h^{-1}): The degradation rate of nutrient components in the rumen is the time it takes for the degradable DM of the feed mixture to be degraded by the rumen microbes per hour.

Rumen outflow rate (%): This represents the speed at which nutrient components of the cereal mixtures exits the rumen according to the rumen incubation time.

Effective degradability - 1% (ED_1): This is the rate at which the nutrient components of the cereal mixtures is efficiently degraded in the rumen at 1% rumen outflow rate per hour. This is used for testing dry dairy cows.

Effective degradability - 5% (ED_5): This is the rate at which the nutrient components of the cereal mixtures is efficiently degraded in the rumen at 5% rumen outflow rate per hour. This is used for testing beef cattle.

Effective degradability - 8% (ED_8): This is the rate at which the nutrient components of the cereal mixtures is efficiently degraded in the rumen at 8% rumen outflow rate per hour. This is used for testing high producing dairy cow.

NLIN program in SAS (version 9.4; SAS Institute, Inc., Cary, NC, USA) was used to calculate the values of a, b, and c.

Comparison of means for degradability components were performed following model;

$Y_i = \mu + \beta_i + \varepsilon_i,$

where Y_i is the observation in the i^{th} silage type, μ is the overall mean, β_i is the i^{th} silage type effect and ε_i is the random error. Comparison of means for effective nutrient degradability was computed for 1%, 5% and 8% rumen outflow rates.

4. RESULTS AND DISCUSSION

4.1. Ruminal Degradability

The ensiled mixtures had high effective degradable DM and CP at the three rumen outflow rates and moderate potentially degradable DM and CP. However, despite the fact that Missouri and Texas showed good results in their DM and CP effective degradability in the rumen, their NDF and ADF effective degradability were poor. In this section, the values from this study are compared to the values reported by other literature data where other forage sources are used.

4.1.1. Ruminal Degradability of DM

The ruminal degradability of DM is an important parameter to measure because DM comprises of the whole potentially digestible nutrients of the forage. In this study, the ruminal degradability of DM at all 3-rumen outflow rate (1%, 5%, and 8%) of both Missouri and Texas mixtures was around 70% on average (Table 3). This means that the mixtures have a good degradability in the rumen of both high and low producing dairy cows. At 8% rumen outflow rate, the DM degradability was a little lower than at 1% and 5% outflow rate, but this is due to the fact that 8% rumen outflow rate is for high producing dairy cows due to their intensive feeding. Missouri showed significantly higher ($P < 0.05$) soluble fraction (10.28%) compared to Texas which showed a soluble fraction of 7.43%. However, the difference between the potentially degradable DM fraction between Missouri and Texas which were 63.76% and 64.90% respectively, was not significant. The effective degradable DM of both mixtures at the three rumen outflow rates (ED_1, ED_5, ED_8) for the ensiled mixtures were high with Missouri showing a higher effective DM ($P < 0.05$) degradability than Texas. The effective DM degradability of Missouri and Texas at 1%/h rumen outflow rate (ED_1) were 73.20% and 71.52%, respectively which connotes a significant difference ($P < 0.05$). At 5%/h rumen outflow rate (ED_5), the difference between the mixtures were not significant (70.09% and 68.40%, respectively). However, at 8%/h rumen outflow rate (ED_8), Missouri showed higher effective DM degradability than Texas (67.96% and 66.27%, respectively), implying a significant difference ($P < 0.05$). According to literature sources, the barley and oats in the mixtures also have excellent dry matter degradability values.

Despite the fact that the rapidly/soluble DM fraction value of the ensiled whole corn plant which was 57.4% (Jurjanz and Monteils, 2004). was higher compared to that of Missouri (10.28%) and Texas (7.43%) in this study, Missouri and Texas still showed a higher ruminal degradation rate of DM than that of the ensiled whole corn plant. The remarkable degradability of barley and winter oats has already been proven by (Raffrenato et al., 2010; Grant and Contach, 2012). They found that barley and winter oat can help enrich the dry matter intake (DMI) of dairy cows and also improve milk production as well. Furthermore, Balde et al. (1993) and Von Keyserlingk et al. (1996), reported that the potential degradable DM fraction values of alfalfa 36.3% and 35.97%, respectively, which are lower than the mean values of Missouri and Texas with 63.76% and 64.90%, respectively. Andrighetto et al (1993) also reported that the DM ruminal degradability value of Italian ryegrass is 60.7% which is lower than the values got from the study of the mixtures at 8% rumen outflow rate (Missouri - 67.96% and Texas - 66.27%) in this current experiment.

Table 3. Ruminal degradability of dry matter (n=96/mixture)

	Missouri	Texas	SEM	P value
Dry matter (DM)				
Soluble fraction (% of DM)	10.28[a]	7.43[b]	0.201	< 0.05
Potentially degradable fraction (% of DM)	63.76	64.90	1.257	ns
Degradation rate (%/h^{-1})	0.78	0.78	0.120	ns
Effective degradability - 1 (%)	73.20[a]	71.52[b]	1.312	< 0.05
Effective degradability - 5 (%)	70.09	68.40	0.882	ns
Effective degradability - 8 (%)	67.96[a]	66.27[b]	0.650	< 0.05

Missouri: 40% of two cultivars of winter triticale + 30% of two cultivars of winter oats + 20% of winter barley + 10% of winter wheat; Texas: 50% of two cultivars of winter triticale + 40% of winter barley + 10% of winter wheat;
ns=not significant

4.1.2. Ruminal Degradability of CP

There were significant differences (P < 0.05) in all ruminal degradable CP components between Missouri and Texas (Table 4). Missouri had a higher (P < 0.05) soluble CP fraction (68.31% of DM) compared to that of Texas (7.44% of DM). However, Missouri had a lower potentially degradable CP fraction (16.96% of DM) compared to Texas (64.90% of DM), implying a significant difference (P < 0.05).

Missouri showed a significantly higher ($P < 0.05$) effective DM degradability ($P < 0.05$) than Texas in all three rumen outflow rates (ED_1, ED_5, ED_8). The effective DM degradability of Missouri and Texas at 1%/h rumen outflow rates (ED_1) were 84.50% and 71.52%, respectively which connotes a significant difference (< 0.05). Also, at 5%/h rumen outflow rate (ED_5), the effective DM degradability of Missouri and Texas were 82.05% and 68.40%, respectively, implying a significant difference ($P < 0.05$). Furthermore, at 8%/h rumen outflow rate (ED_8), Missouri showed an effective DM degradability of 80.63% while Texas showed an effective DM degradability of 66.27%, implying a significant difference ($P < 0.05$).

Missouri and Texas in this study, had significantly different results in terms of the ruminal degradability of CP. Von Keyserlingk et al. (1996) also found that the average rapidly soluble CP fractions of alfalfa and grass hay were 58.99% and 43.97%, respectively, which are lower than the values of Missouri and Texas.

The potentially degradable fraction (% of DM) of CP was higher for Texas, Missouri had 16.96% potentially degradable fraction of CP while Texas had 64.90%. The ruminal degradation rate of CP of Missouri (0.22%) was lower than that of Texas (0.798%).

Table 4. Ruminal degradability of crude protein (n=96/mixture)

	Missouri	Texas	SEM	P value
Crude protein (CP)				
Soluble fraction (% of DM)	68.31^a	7.44^b	0.358	< 0.05
Potentially degradable fraction (% of DM)	16.96^a	64.90^b	0.860	< 0.05
Degradation rate (%/h^{-1})	0.22^a	0.78^b	0.071	< 0.05
Effective degradability - 1 (%)	84.50^a	71.52^b	0.798	< 0.05
Effective degradability - 5 (%)	82.05^a	68.40^b	0.668	< 0.05
Effective degradability - 8 (%)	80.63^a	66.27^b	0.631	< 0.05

Missouri: 40% of two cultivars of winter triticale + 30% of two cultivars of winter oats + 20% of winter barley + 10% of winter wheat; Texas: 50% of two cultivars of winter triticale + 40% of winter barley + 10% of winter wheat;

ns=not significant

The CP effective degradability of Missouri at 8%/h rumen outflow rate (ED_8) was 80.63%, that of Texas was 66.27%. In the case of Missouri silage degradation rate is 0.22 h^{-1}. This value is higher than that measured for normal corn silage (Muazzez, 2018). The rate of decomposition of the Missouri mixture is higher than the values that were measured during the first (0.142 h−1) and second (0.140 h−1) mowing, in the grazeable state (0.110 h−1) and when the ear stage (0.103 h−1). This is true for alfalfa in the first (0.162 h−1) and second (0.154 h−1) cutting stages in the vegetative state, as well as in the early budding stage (0.152 h−1), in the budding stage (0.166 h−1) and at the end of the budding stage (0.137 h−1) to measured values (Amrane and Michelet-Doreau, 1993). Valderrama and Anrique (2011) also reported lower values for alfalfa in the vegetative phase (0.197 h−1), oats (0.294 h−1) and Italian ryegrass (0.157 h−1). Turgut and Yanar (2004) reported the value of alfalfa hay (0.113 h−1). The higher rate of degradability of CP can make the examined mixed silage attractive, because it can be perfectly combined with other plants with a high fiber content for better feed utilization in the feeding of dairy cows. The degradation rate of the slowly degradable fraction of the protein in the Missouri mix silage was higher than that of the corn silage reported by Muazzez (2018) at 0.05 h−1 (60.11%) and 0.08 h−1 (55.88%). The higher EPD value in the present mixed silage can be attributed to the fact that the plants included in the mixture were ensiled at the appropriate stage of the harvest. Comparing the Missouri mixed silage EPD values of 0.05 and 0.08 h−1 with those reported by Valderrama and Anrique (2011), it can be concluded that higher EPD values of 0.05 and 0.08 h−1 are obtained for alfalfa in the vegetative phase (88.25% and 85.16%) and oats (90.80%). In the case of the Italian ryegrass the EPD value is 80.62% at the rumen content outflow rate of 0.08 h−1, so it can be properly matched with the mixture. The EPD value of the silage mixture at the rumen content outflow rate of 0.05 h−1 proved to be better than that of barley (69%, 61%, 56%) and oat (66%, 60%, 56%) at the flowering stage, this is related to the early ripening (Hadjipanayiotou et al., 1996).

4.1.3. Ruminal Degradability of NDF

In this study, the soluble NDF fractions of both ensiled mixtures were low (Table 5). The soluble fraction (% of DM) of NDF of Missouri was 6.96 and 7.65 for Texas. The potentially degradable fraction (% of DM) of NDF for Missouri and Texas were 42.06 and 34.30, respectively. The degradation rate of NDF of both Missouri (0.02) and Texas (0.04) were low. Furthermore, the effective degradability of Missouri at 1%, 5% and 8% were 38.07, 22.26, 18.05 respectively. While the effective degradability of Texas at 1%, 5% and 8% were 32.52, 23.57, 19.73. In all rumen outflow rates, there was no significance between the effective degradability of Missouri and Texas. It is well known that the amount of degradable NDF available in the feed ration has an effect on DMI, rumen function and performance of ruminants (Nousianinen et al., 2009; Zebeli et al., 2012; Bender et al., 2016). It is clear from our results that the NDF content of the examined grain silage represents a significant proportion within the DM. At the same time, the amount of potentially degradable NDF in the rumen (42.1%) cannot be considered an outstanding value as the result obtained falls short of the data reported for Italian ryegrass (59.8%) and corn silage (49.3%) (Andrighetto and et al., 1993).

Table 5. Ruminal degradability of neutral detergent fiber (n=96/mixture)

	Missouri	Texas	SEM	P value
Neutral Detergent Fiber (NDF)				
Soluble fraction (% of DM)	6.96	7.65	0.536	ns
Potentially degradable fraction (% of DM)	42.06	34.30	9.188	ns
Degradation rate (%/h^{-1})	0.02	0.04	0.009	ns
Effective degradability-1 (%)	38.07	32.52	4.467	ns
Effective degradability-5 (%)	22.26	23.57	1.295	ns
Effective degradability-8 (%)	18.05	19.73	0.788	ns

Missouri: 40% of two cultivars of winter triticale + 30% of two cultivars of winter oats + 20% of winter barley + 10% of winter wheat; Texas: 50% of two cultivars of winter triticale + 40% of winter barley + 10% of winter wheat;
ns=not significant

4.1.4. Ruminal degradability of ADF

In this study, the soluble ADF fractions of Missouri (6.26) and Texas (7.41) of the ensiled mixtures were low (Table 6). It is known, that ADF is a measure of the plant components in forages that are the least digestible by ruminants, including cellulose and lignin. The potentially degradable as well as effective degradable ADF were low. The difference between the values of the potentially degradable fraction (% of DM) of both Missouri (39.01%) and Texas (29.73%) was not significant. The low potential and effective ruminal degradability of ADF could be associated with the high ADF contents of ensiled winter cereal mixtures. The degradation rate between Missouri (0.03%) and Texas (0.06%) was also not significant.

Furthermore, the difference between the effective degradability of ADF at 1%/h rumen outflow rate (ED_1) of Missouri (36.25) and Texas (32.96) was not significant. Also, the effective degradability of ADF at 5%/h rumen outflow rate (ED_5) of Missouri (21.91) and Texas (23.97) was not significant. However, at 8%/h rumen outflow rate (ED_8), the effective degradability of ADF was lower ($P < 0.05$) for Missouri (17.78%) than for Texas (20.58%). The effective NDF degradability between them was not significant at 8%/h rumen outflow rate (ED8).

Table 6. Ruminal degradability of acid detergent fibre (n=96/mixture)

	Missouri	**Texas**	**SEM**	**P value**
Acid Detergent Fiber (ADF)				
Soluble fraction (% of DM)	6.26	7.41	0.887	ns
Potentially degradable fraction (% of DM)	39.01	29.73	14.725	ns
Degradation rate (%/h^{-1})	0.03	0.06	0.017	ns
Effective degradability-1 (%)	36.25	32.96	4.992	ns
Effective degradability-5 (%)	21.91	23.97	1.348	ns
Effective degradability-8 (%)	17.78^{a}	20.58^{b}	0.918	< 0.05

Missouri: 40% of two cultivars of winter triticale + 30% of two cultivars of winter oats + 20% of winter barley + 10% of winter wheat; Texas: 50% of two cultivars of winter triticale + 40% of winter barley + 10% of winter wheat;

ns=not significant

6. CONCLUSION

From the results of this study, it is clear that in all three rumen outflow rates (ED1, ED5, and ED8), the two different ensiled winter cereal mixtures (Missouri and Texas) had relatively high effective degradable DM and CP and moderate potentially degradable DM and CP.

However, special attention must be paid when administering these ration formulations especially for high-producing lactating cows due to the low potential and effective ruminal degradable NDF and ADF of these mixtures.

Deliberate actions must be taken to either complement the dietary ration with ideal amount of high ruminal degradable ADF and NDF or to increase the degradability of NDF or ADF (e.g., through the use of exogenous enzymes or other feed additives).

The winter cereal mixtures in this study were found to be as good (potentially better) than some other silage/forage sources primarily used in the diet of high-producing lactating cows which were considered in the literature of the study. This is due to their relatively high effective degradable DM and CP. Therefore, more future experiments should be performed to improve the practical use of the winter cereal-based silage mixtures.

Farmers and producers around the world especially in Nigeria and other tropical countries that suffer greater negative effects from the global warming should adapt this technique of using cereal mixtures (based on available data) to complement their already existing forages sources in order to cut the cost of production of some of the conventional forage sources like maize silage, while still maintaining a high milk production of their dairy cows.

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