UNIVERSIDAD AUTÓNOMA DEL ESTADO DE MÉXICO

MAESTRÍA Y DOCTORADO EN CIENCIAS AGROPECUARIAS Y RECURSOS NATURALES

EVALUACIÓN DE PRADERAS DE ALTA FESCUE (*Festuca arundinacea* cv. Cajun II) EN COMPARACIÓN CON BALLICO PERENNE (*Lolium perenne* cv. Tetragrain) PARA VACAS EN PASTOREO EN SISTEMAS DE PRODUCCIÓN DE LECHE EN PEQUEÑA ESCALA DURANTE LA ÉPOCA SECA

TESIS

QUE PARA OBTENER EL GRADO DE

MAESTRO EN CIENCIAS AGROPECUARIAS Y RECURSOS NATURALES

PRESENTA:

MELCHOR ROSAS DÁVILA

El Cerrillo Piedras Blancas, Toluca, Estado de México, Septiembre de 2019

UNIVERSIDAD AUTÓNOMA DEL ESTADO DE MÉXICO

MAESTRÍA Y DOCTORADO EN CIENCIAS AGROPECUARIAS Y RECURSOS NATURALES

EVALUACIÓN DE PRADERAS DE ALTA FESCUE (*Festuca arundinacea* cv. Cajun II) EN COMPARACIÓN CON BALLICO PERENNE (*Lolium perenne* cv. Tetragrain) PARA VACAS EN PASTOREO EN SISTEMAS DE PRODUCCIÓN DE LECHE EN PEQUEÑA ESCALA DURANTE LA ÉPOCA SECA

TESIS

QUE PARA OBTENER EL GRADO DE

MAESTRO EN CIENCIAS AGROPECUARIAS Y RECURSOS NATURALES

PRESENTA:

MELCHOR ROSAS DÁVILA

COMITÉ DE TUTORES:

DRA. JULIETA GERTRUDIS ESTRADA FLORES

DR. CARLOS MANUEL ARRIAGA JORDÁN

DR. FELIPE LÓPEZ GONZÁLEZ

El Cerrillo Piedras Blancas, Toluca, Estado de México, Septiembre de 2019

Lo conocido es finito, lo desconocido infinito; desde el punto de vista intelectual estamos en una pequeña isla en medio de un océano ilimitable de inexplicabilidad.

T. H. Huxley, 1887.

AGRADECIMIENTOS

Al proyecto de investigación “Evaluación de la sustentabilidad de sistemas de producción de leche en pequeña escala” financiado por el Consejo Nacional de Ciencia y Tecnología (CONACYT) con clave 129449 CB-2009, por la beca otorgada para mis estudios de posgrado.

Al Instituto de Ciencias Agropecuarias y Rurales (ICAR), por ofrecerme la oportunidad de desarrollo académico y personal, siempre recordaré con placer el tiempo aquel en que tuve la satisfacción de conocerle y hacerme participe de su atmósfera científica.

Al Dr. Carlos Manuel Arriaga Jordán de quien atestiguo su calidad humana e interés por el desarrollo de la ciencia. Si en algún momento me he de convertir en un gran hombre, suyo será gran parte de mi éxito.

A la Dra. Julieta Gertrudis Estrada Flores a quien agradezco los consejos que hicieron posible yo pudiese progresar en este complejo proceso.

Al Dr. Felipe López González por su humilde e infinita experiencia, a quien correspondo con mi más profunda amistad y consideración.

A las Técnicas Laboratoristas del Instituto de Ciencias Agropecuarias y Rurales (ICAR), Laura Edith Contreras Martínez y María de Lourdes Maya Salazar por su tutoría durante mi estancia de trabajo de laboratorio.

RESUMEN

El estudio evaluó el desempeño animal, las variables agronómicas, químicas y los costos de alimentación de vacas lecheras en pastoreo de Alta fescue (*Festuca arundinacea* cv. Cajun II) y Ballico perenne (*Lolium perenne* cv. Tetragrain) asociadas con trébol blanco (*Trifolium repens L.*). Todas las vacas además recibieron 5 kg MF/vaca/día de un concentrado comercial. El estudio se desarrolló durante 8 semanas con periodos experimentales de 14 días bajo un enfoque de investigación participativa en sistemas de producción de leche de pequeña escala en el centro de México, se siguió un diseño experimental doble reversible con diez vacas lecheras agrupadas en parejas por tercio de lactación y rendimiento de leche, las cuales fueron asignadas al azar a una de las secuencias de tratamiento. El rendimiento diario de leche, la composición química de la leche, índice de condición corporal, peso vivo, consumo estimado de forraje, altura del pasto, acumulación neta de forraje y la composición química de los alimentos; fueron registrados en los últimos cuatro días de cada período experimental.

No hubo diferencias significativas entre tratamientos ($P \geq 0.05$) para rendimiento de leche, composición química de la leche, peso vivo, índice de condición corporal y consumo estimado de forraje. No obstante, el análisis económico mostró un mayor margen bruto del *Lolium*. La acumulación neta de forraje y la altura de las praderas no presentaron variaciones significativas entre tratamientos ($P \geq 0.05$), pero sí en el contenido de MO, FDA, DIVMO y EM ($P \leq 0.05$) del forraje de las praderas.

ABSTRACT

The study evaluated the animal performance, the agronomic and chemical variables and the feeding costs of dairy cows in grazing pastures of tall fescue (*Festuca arundinacea* cv. Cajun II) and perennial Ballico (*Lolium perenne* cv. Tetragrain) associated with white clover (*Trifolium repens* L.). Cows received 5 kg/day of concentrate. The study run for 8 weeks, with experimental periods of 14 days under a participatory research approach in small-scale milk production systems in central Mexico, a double cross-over experimental design was undertaken with ten cows arranged in pairs per third of lactation and milk yield. Cows were assigned at random to one of the two treatment. Daily milk yield, chemical composition of milk, body condition score, herbage intake, sward height, net herbage accumulation and chemical composition of food; were recorded in the last four days of each experimental period.

There were no differences between treatments (P≥0.05) for milk yield and composition, live weight, body condition score and herbage intake. However, the economic analysis showed a higher gross margin of the *Lolium*. The net herbage accumulation and the sward height showed no differences between treatments (P≥0.05), but there were significant differences (P≤0.05) for OM, ADF and IVOMD between treatments.

ÍNDICE

Página

I. INTRODUCCIÓN

La producción de leche de pequeña escala, ha sido señalada como una actividad clave en el desarrollo y subsistencia del núcleo familiar (Espinoza-Ortega *et al*., 2005).

En México, la lechería se ha desarrollado bajo tres sistemas, cada uno diferenciado entre sí por sus características productivas reflejadas en el aspecto económico, en el que los productores de pequeña escala perciben los menores ingresos (Espinoza-Ortega *et al*., 2005; Espinoza-Ortega *et al*., 2007), asociado sustancialmente, a los elevados costos de alimentación por la compra y uso inmoderado de insumos externos (concentrados), y al bajo precio pagado por litro de leche producido, lo que robustece la vulnerabilidad económica del sistema lechero (Prospero-Bernal *et al*., 2017).

Ante esta tendencia de dificultades, es necesario considerar alternativas de producción sostenibles que permitan enfrentar exitosamente los escenarios competitivos actuales (Pulido *et al*., 2011).

Bajo este contexto, el ballico perenne (*Lolium perenne*) representa la gramínea forrajera de clima templado de mayor valor nutritivo, aunque precisa de una gran cantidad de agua (Arriaga-Jordán *et al*., 1999; Plata-Reyes *et al*., 2018), además, de que las variedades disponibles en México tienen poca persistencia en los pequeños sistemas lecheros, por lo que, es necesario evaluar nuevas variedades disponibles como, la variedad Tetragrain, seleccionada específicamente para una mayor persistencia.

En cambio, la gramínea alta fescue (*Festuca arundinacea*), si bien tiene un menor valor nutritivo que el ballico perenne, pero tiene la ventaja de una mayor rusticidad, tolerancia a las altas temperaturas y al déficit hídrico (Pirnajmedin *et al*., 2016), no obstante, uno de los problemas de la alta fescue es la intoxicación conocida como festucosis que afecta el desempeño de los bovinos; en cambio la variedad Cajun II recientemente introducida en México tiene la ventaja de ser libre de endófitos, constituye una opción importante de ser evaluada.

II. REVISIÓN DE LITERATURA

2.1. Contexto de la lechería de pequeña escala

La producción de leche de pequeña escala, persiste como una actividad meramente rural, pero clave en el desarrollo económico, nutricional, social y territorial de las comunidades campesinas (Hemme y Otte, 2010), contexto que acentúa en un principio básico, asegurar la subsistencia del núcleo familiar (Espinoza-Ortega *et al*., 2005).

En concreto, el pequeño sistema campesino productor de leche, asume una robusta connotación social, prueba del reconocimiento del valor que el sector lechero ostenta, se halla en el interés por los programas de desarrollo de la lechería de pequeña escala en países con economía en vías de desarrollo, donde la malnutrición y la pobreza representan el gran desafío a menguar (Bennett *et al*., 2006; Hemme y Otte, 2010).

En México, la producción de leche en los sistemas de pequeña escala, vislumbran una sucesión de escenarios inseguros e inestables, donde los precios de venta y los costos de producción de la leche, anulan la viabilidad financiera de las pequeñas unidades lecheras, particularmente, por el inmoderado suministro de concentrados comerciales (Prospero-Bernal *et al*., 2017) los cuales en la alimentación del hato representan una gran proporción (70%) de los costos totales de producción (Heredia-Nava *et al*., 2017; Pincay-Figueroa *et al*., 2016), generando incertidumbre concerniente a la capacidad de sostenerse.

No obstante, ante un panorama donde la estructura agropecuaria es heterogénea y compleja, la persistencia de los sistemas productores de leche de pequeña escala se debe al manejo eficiente de ciertos factores, atributo que apela a su capacidad de adaptación, al tomar ventaja de la mano de obra familiar en el proceso de producción y al intensificar el manejo de los recursos existentes en la granja, actividades que acentúan en una mejor eficiencia económica por su carácter implícito de coste de oportunidad (Cortez-Arriola *et al*., 2016; Pincay-Figueroa *et al*., 2016; Posadas-Domínguez *et al*., 2016; Balcao *et* al., 2017).

2.2. Vulnerabilidad de los sistemas de producción de leche de pequeña escala

En México, la industria lechera se ha desarrollado bajo tres sistemas (los especializados, mixtos y de pequeña escala), cada uno diferenciado entre sí por sus características productivas reflejadas en el aspecto económico, en el que los productores de pequeña escala perciben los menores ingresos (Espinoza-Ortega *et al*., 2005; Espinoza-Ortega *et al*., 2007) como resultado a una serie de imperativos entre los que destacan, la menor escala (tamaño del hato y superficie agrícola), la menor producción de leche por vaca al año, la baja adopción de tecnología, a la degradación de los recursos naturales (disponibilidad de agua), a la apertura comercial (importación masiva de grandes volúmenes de leche descremada en polvo al mercado nacional), a la nula asistencia técnica concerniente a la nutrición, al nulo acceso a subsidios, a los altos costos de alimentación por la compra y uso inmoderado de insumos externos (concentrados), a la baja inversión de recursos financieros para la producción de alimentos para el ganado, y al precio pagado por el producto; condiciones que en conjunto deducen un impuesto negativo por litro de leche producido (Bennett *et al*., 2006; Espinoza-Ortega *et al*., 2007; Cortez-Arriola *et al*., 2016; Posadas-Domínguez *et al*., 2016; Prospero-Bernal *et al*., 2017).

Por lo tanto, ante esta tendencia de desventajas productivas que resumen la creciente carencia de activos monetarios, es necesario desarrollar estrategias de alimentación estructuradas al sistema de producción (Heredia-Nava *et al*., 2007).

2.3. Producción de leche en pastoreo de praderas

En general, el uso de forraje en la alimentación del hato, constituye un modelo productivo altamente competitivo, debido a que esta estrategia de alimentación demanda una inversión tecnológica y financiera moderada (Cortez-Arriola *et al*., 2016; Godde *et al*., 2017).

Bajo este contexto, diversos resultados experimentales han probado que la respuesta económico-productiva de los sistemas lecheros, mejora al optimizar el manejo de las limitantes estructurales del sistema de producción (organización y uso de la reducida superficie territorial para el cultivo y manejo de forrajes en pastoreo permanente), permitiendo reducir sustancialmente la necesidad de cantidades excesivas de concentrado, y ofreciendo la ventaja clave de obtener un producto a menor costo (Pulido et al., 2011; Cortez-Arriola *et al*., 2016; Pincay *et al*., 2016; Prospero-Bernal *et al*., 2017; Dale *et al*., 2018). En este tenor, el efecto del pastoreo queda de manifiesto en el rendimiento de leche con producciones medias de 17 kg/vaca/día (5190 kg/vaca/año) (Posadas-Domínguez *et al*., 2016), con contenidos de grasa y proteína en leche homólogos a los estándares establecidos en la norma oficial mexicana (NOM-155-SCFI-2012), y una mejor relación de ingresos sobre los costos de alimentación (Pincay-Figueroa *et al*., 2016).

No obstante, las limitaciones que impone la pradera desde el punto de vista nutricional y productivo a lo largo del año, y a fin de asegurar e intensificar la sostenibilidad del sistema lechero, es necesario considerar alternativas de producción accesibles, que permitan enfrentar los escenarios competitivos actuales (sociales, económicos y ambientales) (Pulido *et al*., 2011; López-González *et al*., 2017), de ahí la necesidad de promover la innovación alimenticia que dé respuesta a los principales retos que la producción plantea; disponer de alimentos de calidad

(Godde *et al*., 2017; Martínez-García *et al*., 2015), mejor adaptados a los fenómenos ambientales, y más resistentes a enfermedades.

Con estos objetivos, el manejo de forrajes con nuevas variedades de gramíneas ofrece grandes oportunidades y nuevos objetivos.

2.4. Rye grass perene (*Lolium perenne*)

En este contexto, el pasto inglés, ryegrass o ballico perenne es considerado como la mejor opción para la producción de forraje en zonas templadas por sus altos rendimientos, calidad nutritiva y habilidad para crecer en gran diversidad de suelos, es una gramínea ideal para praderas de pastoreo. Posee buena digestibilidad y palatabilidad con una capacidad de rebrote rápido y resistencia al pisoteo. Tolera períodos largos de humedad (15 a 20 días), así como suelos ácidos y alcalinos (pH 5.5 a 7.8). Su crecimiento es favorable a temperaturas de 18 °C, pero reduce su crecimiento a temperaturas superiores a 25 °C y no tolera el déficit hídrico (Arriaga-Jordán *et al*., 1999; Turner *et al*., 2012; Barnes *et al*., 2014). Sin embargo, en la región de estudio bajo las condiciones agroecológicas de manejo impuestas por las altas tasas de siembra, el riego limitado y la alta evapotranspiración durante la estación seca se ha observado que las praderas de ballico perenne presentan baja persistencia y son invadidas por el pasto Kikuyo (*Pennisetum Cenchrus clandestinum)*.

2.5. Alta Fescue cv. Cajum II *(Fesctuca arundinacea)*

Festuca spp., es una gramínea perenne cultivada ampliamente en regiones templadas de todo el mundo donde el estrés por calor es un factor que limita su crecimiento y producción (Turner *et al*., 2012) es uno de los principales forrajes frescos de temporada. La forma de aprovechamiento de la festuca es en corte durante la estación fría y en pastoreo, se establece bien en suelos ligeramente ácidos hasta medianamente alcalinos, su hábito de crecimiento es erecto y tiene una buena resistencia al pisoteo o pastoreo. Sin embargo, es una gramínea capaz de formar asociaciones simbióticas con endófitos que producen una gama de compuestos bioactivos entre los que figuran los alcaloides que protegen a la gramínea de los insectos y nemátodos pero que a la vez le confieren características que perjudican el rendimiento animal. El éxito de los endófitos se debe que el hongo infecta sistemáticamente las partes aéreas de la gramínea sin causar enfermedad obteniendo así los nutrientes necesarios para su desarrollo. Entre los efectos negativos de los alcaloides se han descrito el ergonismo y trastornos neuromusculares (Young *et al.,* 2015). La variedad Cajun II es una variedad modificada genéticamente para tener una mejor calidad nutritiva, tolerante al déficit hídrico y las altas temperaturas y está libre de endófitos, de ahí el interés por evaluarla en la región de estudio.

III. JUSTIFICACIÓN

En un contexto económico y político hostil en el cual se desarrolla el sector lechero nacional, el sistema de producción de leche de pequeña escala en particular, opera no sólo bajo una nula intervención gubernamental, sino que además las condiciones ambientales y relaciones económicas han evitado el desarrollo de un sistema sostenible en términos económicos. Desde este punto de vista exclusivo de la actividad lechera de pequeña escala, es necesaria la búsqueda de alternativas productivas que contribuyan a mejorar la eficiencia económica de las pequeñas unidades lecheras.

En tanto que la alimentación del hato representa el mayor rubro de los costos de producción, la perspectiva de un sistema de baja inversión se orienta al uso de gramíneas forrajeras alternativas bajo pastoreo intensivo, en el sentido de que esta estrategia de alimentación constituye la base y la fuente de nutrientes de un sistema de producción a bajo costo, que a diferencia del uso de concentrado o sistemas de corte y acarreo representan elevados costos de producción y una débil rentabilidad económica.

En este sentido, esta propuesta de investigación incide en el aprovechamiento y promoción de gramíneas forrajeras alternativas como innovación en las estrategias de alimentación y como elemento potenciador de la eficiencia económica, logrando con esto, aumentar el nivel de sostenibilidad y competitividad de las pequeñas granjas lecheras.

IV. PREGUNTA DE INVESTIGACIÓN

¿Cuál es el efecto de la implementación del pastoreo de praderas de Alta fescue cv. Cajun II y Ballico perenne cv. Tetragrain sobre el desempeño productivo y composición química de la leche de vacas en lactación en sistemas de producción de leche de pequeña escala?

¿Qué variedad de forraje expresará un mayor potencial de adaptabilidad al medio bajo una alta presión del pastoreo y déficit hídrico, en términos de rendimiento y composición química del forraje?

¿Qué efecto tiene la implementación del pastoreo de praderas sobre la relación costo/beneficio de la producción de leche en sistemas de producción de pequeña escala?

V. HIPÓTESIS

- No hay efecto significativo en el rendimiento de leche, composición química de la leche, índice de condición corporal, peso vivo y consumo total de materia seca de vacas lecheras en pastoreo de praderas de Alta fescue (*Festuca arundinacea* cv. Cajun II) y Ballico perenne (*Lolium perenne* cv. Tetragrain).
- No hay diferencias significativas en la respuesta agronómica y composición química del forraje de praderas de Alta fescue (*Festuca arundinacea* cv. Cajun II) y Ballico perenne (*Lolium perenne* cv. Tetragrain).

VI. OBJETIVOS

6.1. Objetivo general

Evaluar el efecto del pastoreo de praderas de Alta fescue (*Festuca arundinacea* cv. Cajun II) y Ballico perenne (*Lolium perenne* cv. Tetragrain) sobre el comportamiento productivo, en términos de rendimiento de leche y composición química de la leche, índice de condición corporal, peso vivo y consumo total de materia seca de vacas en lactación de sistemas de producción de leche de pequeña escala del centro de México.

6.2. Objetivos específicos

- Evaluar el desempeño animal de las vacas lecheras (rendimiento de leche, composición química de la leche, condición corporal y peso vivo) bajo pastoreo de praderas de Alta fescue (*Festuca arundinacea* cv. Cajun II) y Ballico perenne (*Lolium perenne* cv. Tetragrain).
- Evaluar las variables agronómicas (acumulación neta de forraje (ANF) y altura) y químicas (Materia Seca, Materia Orgánica, Fibra Detergente Ácido, Fibra Detergente Neutro, Proteína Cruda, Digestibilidad Enzimática), de praderas de Alta fescue (*Festuca arundinacea* cv. Cajun II) y Ballico perenne (*Lolium perenne* cv. Tetragrain).
- Estimar el consumo total de materia seca de las vacas lecheras bajo pastoreo de praderas de Alta fescue (*Festuca arundinacea* cv. Cajun II) y Ballico perenne (*Lolium perenne* cv. Tetragrain).

- Realizar un análisis económico de los costos de alimentación de las vacas lecheras bajo pastoreo de praderas de Alta fescue (*Festuca arundinacea* cv. Cajun II) y Ballico perenne (*Lolium perenne* cv. Tetragrain)
- Desarrollar estrategias de alimentación de bajo costo basadas en el uso de forrajes de calidad.

VII. MATERIALES Y MÉTODOS

7.1. Área de estudio

El estudio fue emprendido en la época seca de primavera del 9 de abril al 3 de junio de 2018, en el municipio de Aculco de Espinoza, en el altiplano central de México, a una altitud de 2450 metros sobre el nivel del mar, con un microclima predominante templado sub-húmedo, con lluvias en verano (precipitaciones de 800 mm entre mayo y octubre), una estación invernal no definida (heladas entre mediados de noviembre a finales de febrero), y una temperatura media anual de 13.2°C (INEGI, 2017).

7.2. Animales

Diez vacas criollas encastadas con Holstein, con un promedio de 104 días en lactación y un peso vivo medio de 473 kg, fueron utilizadas en el experimento. Las vacas se agruparon en parejas por tercio de lactación y rendimiento de leche registrado en la semana previa a iniciar el experimento, y cada vaca por pareja fue asignada al azar a una de las secuencias de tratamiento. En el cuadro 1, se muestra una descripción detallada de las vacas utilizadas.

Cuadro 1. Características de los animales utilizados en el experimento.

Grupo	ID animal[1]	PL[2]	PV[3]	ICC[4]	D. LACT.[5]	PARTOS
	6129	25.3	461	2.5	15	5
	6125	18.3	540	2.5	180	1
A	6053	11.4	435	2.5	30	5
	6056	10.4	435	3	180	2
	3575	7.7	371	2	15	4
Media		14.6	448.4	2.5	84	3.4

	6045	21.1	548	2.8	90	6
	3574	19.6	544	2.8	22	5
B	6054	11.4	468	2.8	240	4
	8162	11.1	468	2.5	120	4
	6051	7.2	460	2.5	150	4
Media		14.1	497.6	2.7	124.4	4.6

[1]ID animal= identificación animal, [2]PL= producción de leche, [3]PV= peso vivo, [4]ICC= índice de condición corporal, [5]D. LACT= días en lactación.

7.3. Praderas

El experimento tuvo lugar en 2 praderas ajustadas a 1.11 ha cada una, la pradera 1, establecida con Alta fescue (*Festuca arundinacea* cv. Cajun II); la pradera 2, establecida con ballico perenne (*Lolium perenne* cv. Tetragrain). La dosis de siembra de las praderas fue de 22 kg/ha de semilla de pasto, más 3 kg/ha de semilla de trébol blanco (*Trifolium repens* cv. Fiona). Por fenómenos ambientales críticos, se utilizaron 17 kg más de semilla de pasto para resembrar la pradera 1. La fertilización en la siembra fue de 80N, 80P y 60K kg/ha, y para mantenimiento 50 kg N/ha mensualmente. La carga animal fue de 4.5 vacas/ha por tratamiento.

7.4. Tratamientos

Los tratamientos se describen a continuación:

TxA= pastoreo continuo de Alta fescue por 10 h/día (09.00 a 19.00).

TxB= pastoreo continuo de Ballico perenne por 10 h/día (09.00 a 19.00).

Todas las vacas además recibieron 5.0 kg MF/vaca/día de un concentrado comercial con un contenido de PC de 180 g/kg MS dividido en porciones iguales y, asignado en cada ordeño.

7.5. Variables evaluadas en la pradera

Las variables de las praderas fueron evaluadas cada 14 días. La altura del pasto (cm) se estimó tomando 40 registros por parcela, uno cada 20 pasos siguiendo un patrón en W, con un medidor de pasto de plato ascendente (Heredia-Nava *et al*., 2017).

La ANF (kg MS/ha) se estimó con 24 jaulas de exclusión del pastoreo de 0.25 m^2 (12 jaulas por pradera), y un cuadrante de metal de 0.16 m^2. Las jaulas fueron distribuidas al azar, al inicio y al final de cada período experimental. Se cortaron muestras de forraje a nivel del suelo, fuera de la jaula en el día 0 y dentro de la jaula en el día 14, utilizando el cuadrante de metal. La ANF se estimó por diferencia entre el día 14 y el día 0. Las muestras recolectadas fueron enviadas al laboratorio para la determinación de materia seca y materia orgánica.

Las muestras de forraje (tomadas mediante el método de simulación del pastoreo) y de concentrado para el análisis químico, fueron secadas en un horno de ventilación forzada a 60 °C a peso constante durante 48 horas para la determinación de la materia seca (MS), consecutivamente las muestras fueron molidas e incineradas a 600 °C en un horno mufla para la determinación de la materia orgánica (MO). El contenido de nitrógeno se obtuvo mediante el método Kjeldahl (AOAC, 1990), el resultado se multiplicó por el factor 6.25 para obtener el contenido de proteína cruda (PC), el análisis de fibra detergente neutro (FDN) y fibra detergente ácido (FDA), se determinaron siguiendo los procedimientos Ankom Technology (2005), la estimación de la digestibilidad *in vitro* de la materia orgánica se obtuvo a partir de la microtécnica de Pell y Shofield (1993) a partir de los residuos derivados de la técnica de producción de gas (Theodorou *et al*., 1994). El contenido de energía metabolizable (EM) de los alimentos se calculó con las ecuaciones propuestas por el AFRC (1993), donde ME (MJ/kg MS) = (DIVMO) (0.0157).

7.6. Análisis de costos de producción

Los costos de alimentación de los tratamientos fueron calculados mediante un análisis económico de presupuestos parciales (Dillon and Hardaker, 1980), tomando en consideración todos los costos de alimentación: compra de concentrado comercial y establecimiento de praderas (preparación de la tierra, siembra, semillas, irrigación y fertilización pre y post-siembra).

El valor monetario fue obtenido en pesos y transformados a su equivalente en US$, en una tasa de cambio de peso: dólar de 18.92:1 (datos del Banco de México, 12 octubre 2018)

7.7. Análisis estadístico para la evaluación de los forrajes

Las variables de las praderas fueron analizadas de acuerdo a un diseño de parcelas divididas, donde los tratamientos se consideraron efectos fijos (parcelas mayores), y los períodos de medición efectos aleatorios (parcelas menores) (Stroup *et al*., 1993).

$Yijk = \mu + r_i + T_j + E_k + p_l + T_{pjl} + e_{ijk}$

Donde:

Donde **μ** = media general; $\mathbf{r_i}$ = efecto del bloque, i = 1, 2; $\mathbf{T_j}$ = efecto debido a los tratamientos (parcela mayor), j = 1, 2; $\mathbf{E_k}$ = término del error para las parcelas mayores (r(T)ij); $\mathbf{p_l}$ = efecto debido a los períodos experimentales (parcela menor), k = 1, 2, 3, 4; $\mathbf{T_{pjl}}$ = término de la interacción entre tratamientos y periodos experimentales; y $\mathbf{e_{ijk}}$ = término del error para las parcelas menores. La prueba de Tukey fue aplicada cuando las diferencias en el análisis de varianza fueron significativas ($P \leq 0.05$).

7.8. Variables de respuesta animal

El rendimiento de leche (kg/vaca/día) se registró con una báscula de resorte, del 11 al día 14 de cada período experimental. Se tomaron muestras de leche por vaca por ordeño y se prepararon alícuotas respetando la proporción de cada ordeño. El contenido de proteína y grasa (g/kg) en leche, se determinaron con un analizador automático de ultrasonido (Lactoscan). El contenido de nitrógeno ureico en leche (NUL) (mg/dL) se obtuvo mediante el método colorimétrico enzimático descrito por Chaney y Marbach (1962).

El peso vivo y el índice de condición corporal de las vacas se determinó cada 14 días al inicio y al final de cada período experimental, utilizando una báscula electrónica con capacidad de 1000 kg para el peso vivo, y una escala de 1 a 5 puntos para la condición corporal (Rodenburg, 2000).

7.9. Estimación de consumo

El consumo de materia seca de los forrajes se calculó según el método de "Energía Metabolizable Utilizada" (Baker, 1981), que parte de estimar los requerimientos nutricionales de energía metabolizable de las vacas y resta el aporte de los suplementos.

7.10. Análisis estadístico para la evaluación del desempeño animal

Las variables de respuesta animal se analizaron con un diseño doble reversible con 5 vacas en lactación, y 4 períodos experimentales de 14 días (10 días de adaptación y 4 días de muestreo y registro de datos), según el siguiente modelo estadístico:

$Y_{ijkl} = \mu + S_i + C_{ij} + P_k + T_l + e_{ijkl}$

Donde μ = efecto debido a la media; S_i = efecto debido a la secuencia, i = 1, 2; $C_{i(j)}$ = efecto debido a la vaca dentro de secuencia; j = 1, 2, 3, 4, 5; P_k = efecto debido a los períodos experimentales, k = 1, 2, 3, 4; T_l = efecto debido a los tratamientos, l = 1, 2; y e_{ijkl} = término del error residual.

VIII. RESULTADOS

8.1. Artículo enviado a la revista indexada: Indian Journal of Animal Sciences

-----Mensaje original-----
De: Aruna T Kumar [mailto:icarjournal@gmail.com]
Enviado el: viernes, 21 de junio de 2019 12:00 p. m.
Para: Carlos Manuel Arriaga Jordan <cmarriagaj@uaemex.mx>
Asunto: [IJAnS] Submission Acknowledgement

Dr. CARLOS MANUEL ARRIAGA-JORDAN:

Thank you for submitting the manuscript, "Endophyte-free tall fescue pastures for small-scale dairy systems in the highlands of central Mexico"
to The Indian Journal of Animal Sciences. With the online journal management system that we are using, you will be able to track its progress through the editorial process by logging in to the journal web site:

Manuscript URL:
http://epubs.icar.org.in/ejournal/index.php/IJAnS/author/submission/90921
Username: cmarriagaj

Thank you for considering this journal as a venue for your work.

Aruna T Kumar
The Indian Journal of Animal Sciences

Endophyte-free tall fescue pastures for small-scale dairy systems in the highlands of central Mexico

M. Rosas-Dávila, J. G. Estrada-Flores, F. López-González, and C. M. Arriaga-Jordán

Instituto de Ciencias Agropecuarias y Rurales (ICAR), Universidad Autónoma del Estado de México, Campus UAEM El Cerrillo, El Cerrillo Piedras Blancas, 50090 Toluca, Estado de México, México.

Short Title: Tall fescue pastures for small-scale dairying

Corresponding Author:

Carlos M. Arriaga-Jordán

Instituto de Ciencias Agropecuarias y Rurales (ICAR),

Universidad Autónoma del Estado de México,

Campus UAEM El Cerrillo, El Cerrillo Piedras Blancas,

50090 Toluca, Estado de México, México

Tel / Fax: +52 (722) 296 5552 / 180 61 24 / 481 16 07

E-mail: cmarriagaj@uaemex.mx

Endophyte-free tall fescue pastures for small-scale dairy systems in the highlands of central Mexico

ABSTRACT

The objective was to assess dairy cows in small-scale dairy systems grazing pastures of endophyte-free tall fescue (*Lolium arundinaceum* cv. Cajun II), or perennial ryegrass (*Lolium perenne* cv. Tetragrain), both associated with white clover (*Trifolium repens*). An on-farm double cross-over experiment was undertaken with ten Holstein cows, continuously grazing 10 h/day of Cajun II or Tetragrain pastures, plus 4.6 kg DM of a concentrate/cow/day. Animal variables were milk yield, milk fat and protein content, live-weight, body condition score, and milk urea nitrogen. Pasture variables were sward height, net herbage accumulation, and chemical composition of herbage for CP, NDF, ADF, *in vitro* digestibility of organic matter, and estimated herbage intake from utilised metabolizable energy. An economic analysis compared incomes and feeding costs. There were no statistical differences (P>0.05) in animal or pasture variables. Cajun II endophyte-free tall fescue pasture performed similarly to Tetragrain perennial ryegrass in animal, pasture, and economic variables.

Keywords: Small-scale dairy systems, intensive grazing, *Lolium arundinaceum*, *Lolium perenne*, margin over feed costs.

Small-scale dairy systems (SSDS) are a key activity for the economic, nutritional, social and territorial development of rural communities all over the world (Hemme and Otte, 2010), to assure family livelihoods, and an option to overcome rural poverty (Espinoza-Ortega et al. 2007).

SSDS face difficult scenarios for their viabilities since milk prices have remained static but production costs constantly increase, jeopardizing the financial viability of small dairy farms (Prospero-Bernal et al. 2017). The economic scale is the weakest in the assessment of the sustainability of these systems due to high feeding costs (Prospero-Bernal et al. 2017). Concentrates represent up to 70% of total production costs (Heredia-Nava et al. 2017).

Therefore, there is a need for lower cost feeding strategies that increase the sustainability and competitivity of small dairy farms. An alternative is grazing pasture that has proven lower feeding costs, increased profitability, and enhanced sustainability (Prospero-Bernal et al. 2017).

However, limitations to grazing pastures in small-scale dairy farms are limited irrigation and high evapotranspiration during the dry season, coupled with high stocking rates. These factors reduce the persistency of pastures based on perennial ryegrass (*Lolium perenne*), the choice species for temperate pastures given its high nutritive value; but not tolerant to water deficit. Tall fescue (*Lolium arundinaceum*) is a hardy temperate perennial grass species, which although of lower nutritive value, is more tolerant to water deficit, agroecological and management stresses.

A problem with tall fescue is that old varieties are infected with the endo-phyte fungus *Neotyphodium coenophialum*, which causes tall fescue toxicosis in cattle that affects production and reproductive performance (Waller, 2009). Endophyte-free tall fescue varieties overcome these problems.

Therefore, the objective was to assess the performance of dairy cows in small-scale dairy systems grazing an endophyte-free tall fescue (*Lolium arudinaceum* cv. Cajun II) / white clover (*Trifolium repens* cv. Fiona) pasture or a perennial ryegrass (*Lolium perenne* cv. Tetragrain) / white clover (*Trifolium repens* cv. Fiona) pasture.

MATERIALS AND METHODS

Study area

The experiment took place in the municipality of Aculco, State of Mexico, in the central highlands of the country, located between 20° 00' and 20° 17' N and 99° 40' and 100° 00' W, at a mean altitude of 2440 m. It has a sub-humid temperate climate with rains in summer (mid-May to mid-October), and a dry season during winter and spring (mid-November to mid-May), with frosts between November and February. Mean annual temperature is 13.2°C, and 800 to 1000 mm rainfall (Jaimez-García et al. 2017).

Work followed a participatory livestock research approach (Conroy 2005), through an on-farm experiment with a family of four participating small-scale dairy farmers who manage their land as a single farm. The experiment took place in the spring (dry season) from 9 April to 3 June 2018.

Animal variables

The experiment was a double cross-over design with ten Holstein cows, selected from the farmers' herds. Cows were paired according to days in milk and milk yield on the week previous to the experiment, and members of each pair randomly assigned to treatment sequence. Pre-experimental variables were 14.3±6.2 milk/cow/day, 104±82 days in milk, and 473±56 kg live weight, with no statistical differences (P>0.05) between treatment sequences for these variables.

Milk yield was recorded for four consecutive days with a clock spring balance at the end of each experimental period and expressed as kg milk/cow/day. Individual milk samples per cow and per milking were taken, and milk and protein fat determined with an ultrasound milk analyser. Samples taken same wise were for milk urea nitrogen determination by the enzymatic colorimetric method described by Chaney and Marbach (1962). Live weight (LW) and body condition score on a 1 to 5 scale were recorded at the end of each experimental period.

Herbage intake was estimated indirectly from utilized metabolizable energy following Pulido and Leaver (2001).

Pastures

The experiment took place on two pastures of 1.11 ha each. Pasture 1 was established with tall fescue (*Lolium arundinaceum* cv. Cajun II), and pasture 2 was established with perennial rye grass (*Lolium perenne* cv. Tetragrain); associated with white clover (*Trifolium repens* cv. Fiona).

Seed rate for both pastures was 22 kg grass seed/ha plus 3 kg/ha of white clover. Due to a delay in available irrigation in Pasture 1 that precluded germination and emergence, it was reseeded with 17 kg/ha more of the Cajun II tall fescue seed.

Fertilization at sowing per hectare was 80 N – 80 P – 60 K, and 50 kg N/ha every 28 days. Stocking rate was 4.5 cows/ha, with cows in each treatment sequence grazing each pasture alternatively every 14 day experimental period.

Treatments

Treatments were TxTF = continuous grazing of tall fescue pasture for 10 h/d (9:00 to 19:00 h), and TxPR = continuous grazing of perennial ryegrass pasture for 10 h/d (9:00 to 19:00 h). All cows additionally received 4.6 kg/cow/day of a commercial concentrate with 180 g/kg CP, divided in two equal meals provided at milkings.

Pasture variables

Recording periods at pastures were similar to experimental periods, with pastures nominally divided in two plots as replicates for statistical analysis. Sward height was from 40 measurements per pasture (20 for each nominal plot) with a rising plate grass metre following a 'W' pattern (Heredia-Nava et al. 2017).

Net herbage accumulation was estimated from 12 grazing exclusion cages (0.50 x 0.50 m), six for each nominal plot, randomly distributed on each experimental period. Herbage was cut to ground level with handheld shears within a 0.16 m^2 quadrant outside the cage at the beginning of each experimental period (Day 0) and within the cage (Day 14).

Herbage collected was dried to constant weight at 60 °C for 48 hours in a draught oven for dry matter (DM) determination; and NHA estimated by difference and expressed as kg DM/ha for each period.

Samples of hand-plucked herbage simulating grazing from each pasture were taken during the last day of each period, and composite concentrate samples were dried as described above, and ashed at 600°C in a muffle furnace to determine organic matter (OM).

Methods for the determination of chemical composition of feeds were those reported by Jaimez-García et al. (2017): the Kjeldahl method for crude protein (CP); neutral detergent fibre (NDF), acid detergent fibre (ADF), and *in vitro* digestibility of organic matter (IVDOM) by the micro-bag technique. Estimated Metabolizable (eME) of feeds was calculated from IVDOM with the AFRC (1993) equation.

Economic analysis

Partial budget analysis was performed (Dillon and Hardaker, 1980), taking into account only for feeding costs represented by supplemented concentrate and pasture costs (amortization of establishment costs, irrigation, and fertilization), and incomes from the sale of milk; expressed in US dollars.

Statistical analyses

Pasture variables were analysed with a split plot design by ANOVA where treatments (grass species in pastures) were main plots as fixed effects, and experimental periods as split-plots (random effects) (Kaps and Lamberson, 2004), with the following model:

$Y_{ijkl} = \mu + r_i + T_j + E_k + p_l + Tp_{jl} + e_{ijk}$

Where:

μ = General mean

r = Effect of replicates i = 1,2

T = Effect of pasture treatment (Main Plot) j = 1, 2

E = Error term for Main Plots ［r(T)ij］

p = Effect of experimental periods (split - plot) k = 1, ..., 4

Tp = Interaction term between treatments and measurement periods

e = Error term for split plots

The Tukey test was applied when significant differences were detected ($P \leq 0.05$).

Animal variables were analysed with a double cross-over design with 5 cows per treatment and 4 experimental periods following the treatment sequences TxTF – TxPR – TxTF – TxPR and TxPR – TxTF – TxPR – TxTF. Experimental periods were 14 days long, 10 days for adaptation and 4 days for recording. Fourteen days experimental periods (and shorter periods) are accepted when changes in feeding of dairy cows are not drastic, as has been well established by the INRA-Rennes group in France (Pérez-Prieto et al. 2011).

The model for analyses of animal variables was:

$Y_{ijkl} = \mu + S_i + C_{j(i)} + P_k + T_l + e_{ijkl}$

Where μ = General mean, S = Treatment sequence (i= 1,2), C = Cows within sequence (j= 1, …, 5), P = Experimental periods (k=1, …4), T = Pasture treatments (1,2), and e = Residual error term.

RESULTS AND DISCUSSION

Table 1 shows results for animal variables where there were no significant differences ($P>0.05$) between pasture treatments. There were also no significant differences among periods ($P>0.05$), except for estimated herbage DM intake (HDMI) which was significantly higher ($P<0.05$) in Periods 1 and 2 compared with Periods 3 and 4.

Milk yield showed a pattern that followed changes in live-weight, body condition score, and estimated herbage intake; similar to observations by Hernández-Mendo and Leaver (2006), who mentioned the close relationship linked to DM and energy intake. In the current experiment, estimated herbage intake reflected variations in milk yields.

Table 1. Animal variables.

Variables	Treatment		SEM	Experimental Periods				SEM
	TxTF	TxPR		P1	P2	P3	P4	
MY (kg/cow/d)	13.3	13.5	0.55^{NS}	15.8	14.0	12.4	11.6	0.55^{NS}
Milk fat (g/kg)	36.3	36.1	1.30^{NS}	34.7	37.9	38.8	33.3	1.30^{NS}
Protein (g/kg)	31.1	30.2	0.58^{NS}	30.4	31.8	31.3	29.1	0.58^{NS}
MUN (mg/dl)	8.0	8.4	0.90^{NS}	6.1	6.5	9.0	11.0	0.90^{NS}
LW (kg)	466	471	4.75^{NS}	483	470	459	463	4.75^{NS}
BCS (1-5)	2.4	2.4	0.05^{NS}	2.6	2.4	2.2	2.4	0.05^{NS}
HDMI (kg DM/cow/d	6.3	6.7	0.30^{NS}	7.8^{a}	7.1^{a}	5.6^{b}	5.5^{b}	0.30*

TxTF= Continuous grazing of *Lolium arundinaceaum*, TxPR= Continuous grazing of *Lolium perenne*, MY= Milk Yield, MUN= Milk Urea Nitrogen, LW= Live weight, BCS= Body condition score, HDMI= Estimated herbage DM intake, SEM= Standard error of the mean, NS (P>0.05), * (P<0.05).

Results are lower than reports by Macoon et al. (2011), who reported daily milk yields of 16.5 kg/cow under grazing with supplements. Results, however, are similar to previous reports in the study area (Martínez-García et al. 2015).

Table 2 shows results for pasture variables.

Table 2. Sward height and net herbage accumulation (NHA).

Variables	Treatments		SEMTX	Experimental Periods				SEMex
	TxTF	TxPR		P1	P2	P3	P4	
Sward height (cm)	5.6	5.6	0.18[NS]	7.3[a]	4.1[b]	5.5[a]	5.5[a]	1.42*
NHA (kg DM/ha)	510	500	7.17[NS]	624.0	399.9	485.5	511.0	92.46[NS]
NHA (kg DM/ha/d)	36.3	35.7	0.40[NS]	44.5	28.6	34.7	36.4	6.55[NS]

TxTF= Continuous grazing of *Lolium arundinaceaum*, TxPR= Continuous grazing of *Lolium perenne*, SEMTX= Standard error of the mean for treatments (main plots), SEMex= Standard error of the mean for experimental periods (split-plots 4, NHA= Net herbage accumulation, NS= (P>0.05), *(P<0.05)

There were no differences (P>0.05) for sward height between pasture treatments, although there was a significant difference among periods (P<0.05) with a sharp decline from P1 to P2, to recover slightly in the last two periods. Mean grass metre sward height was above the 5 cm threshold under which difficult grazing conditions may limit herbage intake.

Mean NHA was 505 kg DM/ha/period, representing a daily growth of 36 kg DM/ha/d, with a mean herbage availability of 7.2 kg DM/cow/d. Period 2 showed a decline in NHA, accompanied with the corresponding decrease in sward height that recuperated for Periods 3 and 4.

Although grass metre sward heights may have been above the 5 cm threshold under which grazing conditions limit intake, herbage growth was only 7.2 kg DM/cow/d, limiting herbage intake to just a mean of 6.5 kg DM/cow/d representing a 90% grazing efficiency.

Low NHA was due to the lack of rain and limited irrigation available during the experiment.

As live weight figures show, cows were small and live weight as is usual in these small-scale dairy systems, with low body condition score as is characteristic of Holstein cows, which tends to be lower in small-scale dairy systems given usual underfeeding conditions. Body condition scores were similar to reports of 2.3 by Celis-Alvarez et al. (2016).

Milk fat contents the requirement of 30 g/L established by Mexican standards. The forage to concentrate ratio of 60: 40 enabled the observed milk fat contents. Bargo et al. (2002) reported a 13% milk fat content decrease in grazing cows when concentrate supplementation was above 5 kg DM concentrate/cow/d.

Observed milk fat content in the work herein reported are similar to reports from other countries like Roche et al. (2006) in New Zealand (35.9 g/kg) or Pérez-Prieto et al. (2011) in France (36.6 g/kg).

Herbage intake under grazing is determined by factors as herbage availability, sward height, herbage quality, the type and amount of supplements, and grazing pressure (Oliveira et al. 2007). Ample herbage allowance, above 20 kg DM/cow/d enables high herbage intakes (Bargo et al. 2002). Herbage allowance was low with just over 7.2 kg/cow/d.

The low NHA hampered herbage intake in spite of adequate grass metre sward height, not following statements by Pulido and Leaver (2001) who reported increased herbage intake, and increased milk yields, with increasing sward heights.

Table 3 shows the chemical composition of the simulated grazing samples of herbage. There were significant differences (P<0.05) between treatments for OM, ADF, IVDOM, and eME, with tall fescue showing higher IVDOM which resulted in a slightly higher eME value. There were significant differences (P<0.05) among periods for all variables except OM.

Herbage quality in both pastures was high, with over 180 g CP/kg DM, and between 400 and 500 g NDF/kg DM, with high eME; both sustaining moderate milk yields in spite of restrictions to herbage intake due to low NH

Table 3. Chemical compositon of herbage (g/kg DM) and estimated metabolizable energy (eME) (MJ/kg DM).

Variables	Treatments		SEMTX	Experimental Periods				SEMTx
	TxTF	TxPR		P1	P2	P3	P4	
DM	252.2	205.9	32.78^{NS}	214.1^{b}	263.6^{a}	218.1^{a}	220.4^{a}	23.19*
OM	869.5	834.2	24.92*	863.4	840.0	855.5	848.5	9.95^{NS}
CP	175.3	215.2	28.24^{NS}	169.5^{b}	174.0^{a}	227.7^{a}	209.8^{a}	28.18*
NDF	471.8	452.0	13.99^{NS}	455.2^{a}	481.9^{a}	467.3^{a}	443.1^{b}	16.62*
ADF	230.3	215.2	6.73*	225.5^{a}	241.9^{a}	215.3^{a}	208.4^{b}	14.54*
IVDOM	639.7	617.6	10.56*	640.3^{a}	594.3^{b}	655.0^{a}	624.9^{a}	25.98*
eME	10.0	9.7	0.25*	10.0^{a}	9.3^{b}	10.3^{a}	9.8^{a}	0.41*

TxTF= Continuous grazing of *Lolium arundinaceaum*, TxPR= Continuous grazing of *Lolium perenne*, SEMTx= Standard error of the mean for treatments (main plots), SEMex= Standard error of the mean for experimental periods (split-plots 4, , DM= Dry matter, OM= Organic matter, CP= Crude proetin, NDF= Neutral detergent fibre, ADF= Acid detergent fibre, IVDOM= *In vitro* digestibility of organic matter, eME= Estimated metabolizable energy, NS= (P>0.05), *(P<0.05)

Table 4 shows the partial budget analysis for feeding costs and returns from milk sales expressed in US dollars.

Table 4. Economic analyses.

	TxTF	TxPR
Feeding costs		
Concentrate (USD$)	425.04	425.04
Pasture (USD$)	74.08	71.28
Total (USD$)	499.12	496.32
Feeding cost per cow (USD$/cow)	99.82	99.26
Daily feeding cost per cow (USD$/cow/d)	1.78	1.77
Feeding cost per kg (USD$/kg milk)	0.134	0.131
Incomes		
Milk sales (USD$)	1,005.48	1,020.60
Margins over feeding costs		
Total margins (USD$)	506.36	524.28
Margin per cow (USD$/cow)	101.27	104.85
Margin per day (USD$/d)	9.04	9.36
Margin per kg milk (USD$/kg milk)	0.135	0.138
Income over feeding costs ratio (USD$)	2.01	2.05

Given the slightly higher cost of tall fescue seed, there is a minor non-significant advantage for the perennial ryegrass pasture.

The economic analysis showed a marginal advantage of the Tetragrain perennial ryegrass pasture compared to the endophyte-free Cajun II tall fescue, given the higher price of seed, and therefore higher amortization of establishment costs, and the numerically lower milk yield.

Both pasture treatments showed similar profit margins expressed as the margin over feeding cost ratio, that for both pastures was above USD$2.00.

An important aspect to note is the cost of concentrate per kg DM that was 8.5 times more expensive than the cost per kg DM of pasture, representing 85% of feeding costs.

Prospero-Bernal et al. (2017) identified the economic scale as the weak point in the sustainability of these small-scale dairy systems, where feeding costs were identified as areas of opportunity given that concentrates comprise a large percentage of those costs.

Results showed that Cajun II endophyte-free tall fescue pasture under grazing performed similarly to the Tetragrain perennial ryegrass pasture in terms of animal performance, herbage growth and chemical composition, and in the economic analyses. However, being tall fescue more tolerant to water deficit conditions, results encourage further research on the role that tall fescue may play under grazing in the feeding strategies of small-scale dairy systems.

Acknowledgments

Authors express gratitude to the farmers who participated in this experiment, whose privacy and that of their family is respected by not disclosing their names. Our gratitude also to Ms. Maria de Lourdes Maya Salazar and Ms. Laura Edith Martínez- Contreras for laboratory analyses. This work was undertaken thanks to funding by the Autonomous University of the State of Mexico (*Universidad Autónoma del Estado de México*) through grant UAEM 3676/2014/CIA, and the Mexican National Council for Science and Technology (*Consejo Nacional de Ciencia y Tecnología–CONACYT*) for the postgraduate grant for Melchor Rosas-Dávila.

References

AFRC. Animal and Food Research Council. 1993. Energy and Protein Requirements for Ruminants. An advisory manual prepared by the AFRC Technical Committee on Response to Nutrients. 159. CAB International, Wallinford, UK.

Bargo F, Muller LD, Delahoy JEm Cassidy TW. 2002. Milk Response to Concentrate Supplementation of High Producing Dairy Cows Grazing at Two Pasture Allowances. *Journal of Dairy Science* **85:** 1777-1792.

Celis-Alvarez MD, López-González F, Martínez-García CG, Estrada-Flores JG, Arriaga-Jordán C M. 2016. Oat and ryegrass silage for small-scale dairy systems in the highlands of central Mexico. *Tropical Animal Health and Production* **48:** 1129-1134.

Chaney L, Marbach E. 1962. Modified reagents for determination of urea and ammonia. *Clinical Chemistry* **8:** 130-132.

Conroy C. 2005. Participatory livestock research. 304. ITDG Publishing, Warwickshire, UK.

Dillon J, Hardaker JB. 1980. Farm management research for small farmer development. FAO Agricultural Services Bulletin 41, Food and Agriculture Organization (FAO), Rome, Italy.

Espinoza-Ortega A, Espinosa-Ayala E, Bastida-López J, Castañeda-Martínez T, Arriaga-Jordán CM. 2007. Small-scale dairy farming in the highlands of central Mexico: technical, economic and social aspects and their impact on poverty. *Experimental Agriculture* **43**: 241-256.

Hemme T, Otte J. 2010. Pro-poor livestock policy initiative. Status and prospects for smallholder milk production-a global perspective. Food and Agriculture Organization (FAO), Rome, Italy.

Heredia-Nava D, López-González F, Albarrán-Portillo B, Arriaga-Jordán CM.(2017. Supplementation with soya bean meal during the dry season for dairy cows fed on pasture and maize silage in the highlands of Mexico. *Journal of Livestock Science* **8:** 21-27.

Hernández-Mendo O, Leaver JD. 2006. Production and behavioural responses of high a low yielding dairy cows to different periods of access to grazing or to a maize silage and soyabean meal diet fed indoors. *Grass and Forage Science* **6:** 335-346.

Jaimez-García AS, Heredia-Nava D, Estrada-Flores JG, Vicente F, Martínez-Fernández A, López-González F, Arriaga-Jordán CM. 2017. Maize silage as sole forage source for dairy cows in small-scale systems in the highlands of central Mexico. *Indian Journal of Animal Sciences* **87** (6): 752-756

Kaps M, Lamberson W. 2004. Change-over designs. Chapter 14. In: M. Kaps and W. Lamberson (eds), Biostatistics for Animal Science, Cromwell Press, Trowbridge, UK. 294 – 312.

Macoon B, Sollenberger LE, Staples CR, Portier KM, Fike JH, Moorell JE. 2011. Grazing management and supplementation effects on forage and dairy cow performance on cool-season pastures in the south-eastern United States. *Journal of Dairy Science* **94**: 3949-3959.

Martínez-García CG, Rayas-Amor AA, Anaya-Ortgea JP, Martínez-Castañeda FE, Espinoza-Ortega A, Prospero-Bernal F, Arriaga-Jordán CM. 2015. Performance of small-scale dairy farms in the highlands of central Mexico during the dry season under traditional feeding strategies. *Tropical Animal Health and Production* **47:** 331-337.

Oliveira DE, Medeiros SR, Tedeschi LO, Aroeira LJM, Silva SC. 2007. Estimating forage intake of lactating dual-purpose cows using chromium oxide and n-alkanes as external markers. *Scientia Agricola* **64:** 103-110.

Pérez-Prieto LA, Peyraud JL, Delagarde R. 2011. Pasture intake, milk production and grazing behaviour of dairy cows grazing low-mass pastures at three daily allowances in winter. *Livestock Science* **137**: 151-160.

Prospero-Bernal F, Martínez-García CG, Olea-Pérez R, López-González F, Arriaga-Jordán CM. 2017. Intensive grazing and maize silage to enhance the sustainability of small-scale dairy systems in the highlands of Mexico. *Tropical Animal Health and Production* **49**: 1537–1544.

Pulido RG, Leaver JD. 2001. Quantifying the influence of sward height, concentrate level and initial milk yield on the milk production and grazing behaviour of continuously stocked dairy cows. *Grass Forage Science* **56:** 57-67.

Roche JR, Berry DP, Kolver ES. 2006. Holstein-Friesian strain and feed effects on milk production, body weight, and body condition score profiles in grazing dairy cows. *Journal of Dairy Science* **89:** 3532–3543.

Waller JC. 2009. Endophyte effects on cattle. In HA Frigourg, DB Hannaway, CP. West (eds.) Tall fescue for the twenty-first century. Chapter 16. Monograph 53, American Society of Agronomy Inc., Crop Science Society of America Inc. and Soil Science Society of America, Inc.. Madison, Wisconsin. pp. 289 – 319.

IX. CONCLUSIONES GENERALES

- La respuesta animal en términos de rendimiento de leche, composición química de la leche, peso vivo, índice de condición corporal y consumo estimado de forraje no presentaron variaciones estadísticas significativas entre los tratamientos.
- La respuesta agronómica de las praderas en términos de altura del pasto y acumulación neta de forraje no presentaron variaciones significativas entre los tratamientos.
- La respuesta química de las praderas presentó diferencias estadísticas significativas en términos de MO, DIVMO y EM a favor de la *Festuca arundinacea* cv Cajun II.
- El contenido nutricional de las praderas es capaz de cubrir los requerimientos mínimos de energía y proteína de las vacas, lo cual podría reducir el uso de suplementos alimenticios y por lo tanto de los costos de alimentación.
- La incorporación del pastoreo como estrategia de alimentación en los sistemas lecheros de pequeña escala, impacta directamente sobre la rentabilidad del hato y la disminución de la pobreza.
- La producción de leche de pequeña escala es una actividad que ofrece grandes beneficios a las familias campesinas a través de la generación de ingresos diarios.
- El pastoreo directo permite sostener rendimientos moderados de leche por vaca además de reducir la carga de trabajo físico para del productor.
- La presión actual sobre los costos de producción y los precios de venta de la leche que enfrentan los productores sugiere seguir buscando alternativas de alimentación a base de forrajes alternativos que permitan reducir los costos de alimentación y mejorar la rentabilidad.

X. REFERENCIAS BIBLIOGRÁFICAS

AFRC. Animal and Food Research Council., (1993). Energy and protein requirements of ruminants. An advisory manual prepared by the AFRC technical committee on response to nutrients. 159. CAB International, Wallingford, UK.

ANKOM TECHNOLOGY., (2005). Procedures (for NDF and ADF). In vitro true digestibility using the DAISY II incubator. http://www.ankom.com

AOAC., (1990). *Official Method of Analysis. The Association of Official Analytical Chemists*, 15th ed. Arlington, Virginia: Association of Official Analytical Chemists.

Arriaga-Jordán, C., Espinoza, A., Albarrán-Portillo, B., Castelán-Ortega, O., (1999). Roducción de leche en pastoreo de praderas cultivadas: una alternativa para el Altiplano Central. Ciencia Ergo Sum, 6(3), 290-300.

Baker, R. D., (1981). Estimating herbage intake from animal performance in: Leaver JD (ed.), *Herbage intake handbook*. Maidenhead: British Grassland Society.

Balcao, L. F., Longo, C., Costa, J. H. C., Uller-Gómez, C., Machado-Filho, L. C. P. and Hotzel, M. J., (2017). Characterization of smallholding dairy farms in southern Brazil. Animal Production Science, 57, 735-745.

Bargo, F., Muller, L. D., Delahoy, J. E. and Cassidy, T. W., (2002). Milk Response to Concentrate Supplementation of High Producing Dairy Cows Grazing at Two Pasture Allowances. Journal of Dairy Science, 85, 1777-1792.

Barnes, B. D., Kopeck´y, D., Lukaszwski, A. J. and Baird, J. H., (2014). Evaluation of Turf-type Interspecific Hybrids of Meadow Fescue with Perennial Ryegrass for Improved Stress Tolerance. Crop Science, 54, 355-365.

Bennett, A., Lhoste, F., Crook, J. and Phelan J., (2006). Futuro de la producción lechera en pequeña escala, Informe pecurio.

Celis-Alvarez, M. D., López-González, F., Martínez-García, C. G., Estrada-Flores, J. G. and Arriaga-Jordán, C. M., (2016). Oat and ryegrass silage for small-scale dairy systems in the highlands of central Mexico. Tropical Animal Health and Production, 48, 1129-1134.

Chaney, A. L., and Marbach, E. P., (1962). Modified reagents for determination of urea and ammonia. Clinical Chemistry, 8, 130-132.

Conroy, C., (2005). Participatory livestock research. 304. ITDG Publishing, Warwickshire, UK.

Cortez-Arriola, J., Groot, J. C. J., Rossing, W. A. H., Scholberg, J. M. S., Améndola-Massiotti, R. D. and Tittonell, P., (2016). Alternative options for sustainable intensification of smallholder dairy farms in North-West Michoacán, Mexico. Agricultural Systems, 144, 22-32.

Dale, A., Laidlaw, A., McGettrick, S., Gordon, A. and Ferris, C., (2018). The effect of grazing intensity on the performance of high-yielding dairy cows. Grass and Forage Science, 1-13.

Dillon, J. and Hardaker J. B., (1980). Farm management research for small farmer development. FAO Agricultural Servises Bulletin 41, Food and Agriculture Organization (FAO), Rome, Italy.

Espinoza-Ortega, A., Álvarez-Macías, A., Del Valle, M. C. y Chauvete, M., (2005). La economia de los sistemas campesinos de produccion de leche en el estado de México. Técnica pecuaria en México, 43, 1, 39-56.

Espinoza-Ortega, A., Espinosa-Ayala, E., Bastida-López, J., Castañeda-Martínez, T. and Arriaga-Jordán, C. M., (2007). Small scale dairy farming in the highlands of central Mexico: technical economic and social aspects and their impact on poverty. Experimental Agriculture, 43, 241-256.

Godde, C. M., Garnett, T., Thornton, P. K., Ash, A. J. and Herrero, M., (2017). Grazing systems and intensification: Drivers, dynamics, and trade-offs. Global Food Security.

Hemme, T. and Otte, J., (2010). Pro-poor livestock policy initiative. Status and prospects for smallholder milk production-a global perspective. Roma, Italia: ed. FAO.

Heredia-Nava, D., Espinoza-Ortega, A., González-Esquivel, C. E. and Arriaga-Jordán, C. M., (2007). Feeding strategies for small-scale dairy systems based on perennial (*Lolium perenne*) or annual (*Lolium multiflorum*) ryegrass in the central highlands of Mexico. Tropical Animal Health and Production, 39, 179-188.

Heredia-Nava, D., López-González, F., Albarrán-Portillo, B., and Arriaga-Jordán, C. M., (2017). Supplementation with soya bean meal during the dry season for dairy cows fed on pasture and maize silage in the highlands of Mexico. Journal of Livestock Science, 8, 21-27.

Hernández-Mendo, O. and Leaver, J. D., (2006). Production and behavioural responses of high a low yielding dairy cows to different periods of access to grazing or to a maize silage and soybean meal diet fed indoors. Grass and Forage Science, 6, 335-346.

INEGI-Instituto Nacional de Estadística y Geografía., (2017). Aculco. http://www.beta.inegi.org.mx/app/buscador/default.html?q=aculco

Jaimez-García, A. S., Heredia-Nava, D., Estrada-Flores, J. G., Vicente, F., Martínez-Fernández, A., López-González, F. and Arriaga-Jordán, C. M., (2017). Maize silage as sole forage source for dairy cows in small-scale systems in the highlands of central Mexico. Indian Journal of Animal Sciences, 87 (6), 752-756.

Kaps, M. and Lamberson, W., (2004). Change-over designs. Chapter 14. In: M. Kaps and W. Lamberson (eds), Biostatistics for Animal Science, Cromwell Press, Trowbridge, UK. 294 – 312.

López-Gozález, F., Rosas-Dávila, M., Celis-Alvarez, M. D., Morales-Almaraz, E., Domínguez-Vara, I. A. and Arriaga-Jordán, C. M., (2017). Milk production under grazing of different pasture grasses in small-scale dairy systems in the highlands of central Mexico. Livestock Science, 8, 92-97.

Macoon, B., Sollenberger, L. E., Staples, C. R., Portier, K. M., Fike, J. H. and Moorell, J. E., (2011). Grazing management and supplementation effects on forage and dairy cow performance on cool-season pastures in the south-eastern United States. Journal of Dairy Science, 94, 3949-3959.

Martínez-García, C. G., Rayas-Amor, A. A., Anaya-Ortega, J. P., Matínez-Castañeda, F. E., Espinoza-Ortega, A., Propero-Bernal, F. and Arriaga-Jordan, C. M., (2015). Performance of small-scale dairy farms in the highlands of central Mexico during the dry season under traditional feeding strategies, 47, 331-337.

NOM. Norma Oficial Mexicana., (2012). NOM-155-SCFI-2012. Leche, denominaciones, especificaciones fisicoquímicas, información comercial y métodos de prueba. México. D.F.

Oliveira, D. E., Medeiros, S. R., Tedeschi, L. O., Aroeira, L. J. M. and Silva, S. C., (2007). Estimating forage intake of lactating dual-purpose cows using chromium oxide and n-alkanes as external markers. Scientia Agricola, 64, 103-110.

Pell, A.N., Schofield, P., (1993). Computerized monitoring of gas production to measure forage digestion in vitro. J. Dairy Sci, 76, 1063-1073.

Pérez-Prieto, L. A., Peyraud J. L. and Delagarde, R., (2011). Pasture intake, milk production and grazing behaviour of dairy cows grazing low-mass pastures at three daily allowances in winter. Livestock Science, 137, 151-160.

Pincay-Figueroa, P. E., López-González, F., Velarde-Guillén, J., Heredia-Nava, D., Matínez-Castañeda, F. E., F. V., Férnandez A. M. and Arriaga-Jordán, C. M., (2016). Cut and carry vs. Grazing of cultivated pastures in small scale dairy systems in the central highlands of Mexico. Journal of Agriculture and Environment for International Development, 110(2), 349-363.

Pirnajmedin, F., Majidi, M. M. and Gheysari, M., (2016). Survival and recovery of tall fescue genotypes: association with root characteristics and drought tolerance. Grass and Forage Science, 71, 632-640.

Plata-Reyes, D. A., Morales-Almaraz, E., Martínez-García, C. G., Flores-Calvete, G., López-González, F., Prospero-Bernal, F., Valdez-Ruiz, C. L., Zamora-Juárez, Y. G. and Arriaga-Jordán, C. M., (2018). Milk production and fatty acid profile of dairy cows grazing four grass species pastures during the rainy season in small-scale dairy systems in the highlands of Mexico. Trop. Anim. Health Prod, 50, 1797-1805.

Posadas-Domínguez, R. R., Callejas-Juárez, N., Arriaga-Jordán, C. M. and Martínez-Castañeda, F.E., (2016). Economic and financial viability of small-scale dairy systems in central Mexico: economic scenario 2010-2018. Tropical Animal Health and Production, 48(8), 1667-1671.

Prospero-Bernal, F., Martínez-García, C. G., Olea-Pérez, R., López-González, F. and Arriaga-Jordán, C. M., (2017). Intensive grazing and maize silage to enhance the sustainability of small-scale dairy systems in the highlands of Mexico. Tropical Animal Health and Production, 49, 1537–1544.

Pulido, R. G. and Leaver J. D., (2001). Quantifying the influence of sward height, concentrate level and initial milk yield on the milk production and grazing behaviour of continuously stocked dairy cows. Grass Forage Science, 56, 57-67.

Pulido, R., Parga, J., Lanuza, A. y Balocchi, O., (2011). Suplementacion de las vacas lecheras a pastoreo. America, Osorno, Chile.

Roche, J. R., Berry, D. P. and Kolver, E. S., (2006). Holstein-Friesian strain and feed effects on milk production, body weight, and body condition score profiles in grazing dairy cows. Journal of Dairy Science, 89, 3532–3543.

Rodenburg, J., 2000. Body condition scoring for dairy catlle. http://www.omafra.gov.on.ca/english/livestock/dairy/facts/00-109.htm

Stroup, W. W., Hildebrand, P. E., and Francis, C. A., (1993). Farmer participation for more effective research in sustainable agricultura. In: Regland J. and Rattan L. (Editors). Technologies for Sustainable Agriculture in the Tropics. Soil Science Society of America, Inc., American Society of Agronomy, Inc, and Crop.

Theodorou, M. K., Williams, B. A., Dhanoa, M. S., McAllan, A. B., France, J., (1994). A simple gas production method using a pressure transducer to determine the fermentation kinetics of ruminants feeds. Animal Feed Science and Technology, 48, 185-197.

Turner, L. R., Holloway-Phillips, M. M., Rawnsley, R. P., Donaghy, D. J. and Pembleton, K. G., (2012). The morphological and physiological responses of perennial ryegrass (*Lolium perenne* L.), cocksfoot (*Dactylis glomerata* L.) and tall fescue (*Festuca arundinacea* Shre.; syn. *Schedonorus phoenix* Scop.) to variable water availability. Grass and forage science, 67, 507-518.

Waller, J. C., (2009). Endophyte effects on cattle. In HA Frigourg, DB Hannaway, CP. West (eds.) Tall fescue for the twenty-first century. Chapter 16. Monograph 53, American Society of Agronomy Inc., Crop Science Society of America Inc. and Soil Science Society of America, Inc. Madison, Wisconsin, pp. 289 – 319.

Young, C. A, Hume, D. E. and Mc Culley., (2015). Forages and pastures symposium: fungal endophytes of tall fescue and perennial ryegrass: Pasture friend or foe. Journal of Animal Science, 91, 2379–2394.

XI. ANEXOS

11.1. Co-Autor del artículo enviado a la revista Agricultural Systems: "Evaluation of Native and Hybrid Maize Silages (Zea mays) for Sustainable Milk Production in Mexico"

Manuscript Details

Manuscript number AGSY_2018_399

Title Evaluation of Native and Hybrid Maize Silages (Zea mays) for Sustainable Milk Production in Mexico

Article type Research Paper

Abstract

Maize cultivation and dairy cattle represent two of the main economic activities in Mexico, with corn silage a practical option due to its concentration of soluble carbohydrates and dry matter yields. The objective of the present study was to determine the forage quality and forage yield (ton / ha) of the corn silage produced in Mexico and estimate potential milk production with the Milk 2006 program. For this purpose, 13 studies carried out in Mexico, with a total of 144 records, were analyzed according to study area (north vs. center of Mexico) and variety (native vs. hybrid). The data were analyzed using a completely randomized statistical design. The results indicate that the forage yield of DM / ha, and the production of milk / ha were higher ($P < 0.0001$) for the central region with respect to the northern region, but the density of plants in the northern region with respect to the center was higher ($P < 0.0001$). Regarding the variety, the forage yield per ha (ton DM / ha) was higher for the hybrids ($P < 0.0018$), whereas for milk production (kg milk/ ha) the native silages produced more ($P < 0.05$) than the hybrids. A positive correlation was observed ($P < 0.01$) for DM production (ton / ha) and kg milk / ha, and negative correlation ($P < 0.05$) was observed for DM yield and crude protein content and DM digestibility. Likewise, a positive correlation was observed ($P < 0.01$) for NDF digestibility with respect to TND, and for the content of NEL (MJ / kg DM) and kg milk / ton DM. The native maize of Mexico thus has the potential to provide greater production of milk / ha and per ton DM with respect to hybrid maize.

Keywords corn; forage; milk production; silage; high valleys of Mexico.

Corresponding Author Manuel Gonzalez Ronquillo

Corresponding Author's Institution Universidad Autonoma del Estado de Mexico

Order of Authors Lizbeth Robles Jimenez, Melchor Rosas Davila, Jorge Osorio Avalos, Alfonso Chay Canul, Carlos Palacios Riocerezo, Octavio Castelan-Ortega, Manuel Gonzalez Ronquillo

Suggested reviewers Paula Toro-Mujica, Jose Dubeux Jr., Antonio Faciola, Mårten Hetta

Submission Files Included in this PDF

File Name [File Type]

Cover letter Liz AgricSys April 2018.docx [Cover Letter]

Highlights Liz maices.docx [Highlights]

Liz 16 abril 2018 RV MGR Final.docx [Manuscript File]

Tables maices Robles Jimenez 17 abril2018.docx [Supporting File]

To view all the submission files, including those not included in the PDF, click on the manuscript title on your EVISE Homepage, then click 'Download zip file'.

Research Data Related to this Submission

There are no linked research data sets for this submission. The following reason is given:
Data will be made available on request

UAEM | Universidad Autónoma del Estado de México
Facultad de Medicina Veterinaria y Zootecnia

Toluca, Mexico April 17, 2018

Agricultural systems
Editor
S. Dogliotti,
Universidad de la República, Montevideo, Uruguay

Dear Editor, we submit the Manuscript

Title: **Evaluation of Native and Hybrid Maize Silages (Zea mays) for Sustainable Milk Production in Mexico**

Autors: Lizbeth E. Robles Jimenez, Melchor Rosas Davila, Jorge Osorio Avalos, Alfonso J. Chay-Canul, Carlos Palacios Riocerezo, Octavio Alonso Castelan Ortega, Manuel Gonzalez Ronquillo

Article Type: Research

In order to be considered in Agricultural systems

The present study determine the forage quality and forage yield (ton / ha) of the corn silage produced in Mexico and estimate potential milk production with the Milk 2006 program.

Sincerely,
The authors

PATRIA, CIENCIA Y TRABAJO

Dr. Manuel Gonzalez Ronquillo
Research

DNA

Ccp. Archivo
Email: mrg@uaemex.mx

Highlights

1. Corn forage yield per ha (ton DM / ha) was higher for the hybrids
2. Native corn silages produced more milk production (kg milk/ ha) than the hybrids.
3. A positive correlation was observed for DM production (ton / ha) and kg milk / ha,
4. A positive correlation was observed for NDF digestibility with respect to the content of NEL (MJ / kg DM) and kg milk / ton DM.
5. The native maize of Mexico thus has the potential to provide greater production of milk / ha and per ton DM with respect to hybrid maize.

Evaluation of Native and Hybrid Maize Silages (Zea mays) for Sustainable Milk Production in Mexico

Lizbeth E. Robles Jimenez[1], Melchor Rosas Davila[1], Jorge Osorio Avalos[1], Alfonso J. Chay-Canul[2], Carlos Palacios Riocerezo[3], Octavio Alonso Castelan Ortega[1], Manuel Gonzalez Ronquillo[1]*

[1]Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma del Estado de México. 50000. Instituto Literario 100, Toluca, Estado de México, Mexico.

[2]División Académica de Ciencias Agropecuarias, Universidad Juárez Autónoma de Tabasco. Carretera Villahermosa-Teapa, km 25, R/A. La Huasteca 2ª Sección, CP 86280, Villahermosa, Tabasco, Mexico.

[3]Departamento de Construcción y Agronomía, Facultad de Ciencias Agrarias y Ambientales, Universidad de Salamanca, Avda. Filiberto Villalobos, 119. CP 37007 Salamanca, Spain.

Abstract

Maize cultivation and dairy cattle represent two of the main economic activities in Mexico, with corn silage a practical option due to its concentration of soluble carbohydrates and dry matter yields. The objective of the present study was to determine the forage quality and forage yield (ton / ha) of the corn silage produced in Mexico and estimate potential milk production with the Milk 2006 program. For this purpose, 13 studies carried out in Mexico, with a total of 144 records, were analyzed according to study area (north vs. center of Mexico) and variety (native vs. hybrid). The data were analyzed using a completely randomized statistical design. The results indicate that the forage yield of DM / ha, and the production of milk / ha were higher ($P < 0.0001$) for the

1

central region with respect to the northern region, but the density of plants in the northern region with respect to the center was higher (P <0.0001). Regarding the variety, the forage yield per ha (ton DM / ha) was higher for the hybrids (P <0.0018), whereas for milk production (kg milk/ ha) the native silages produced more (P <0.05) than the hybrids. A positive correlation was observed (P <0.01) for DM production (ton / ha) and kg milk / ha, and negative correlation (P <0.05) was observed for DM yield and crude protein content and DM digestibility. Likewise, a positive correlation was observed (P <0.01) for NDF digestibility with respect to TND, and for the content of NEL (MJ / kg DM) and kg milk / ton DM. The native maize of Mexico thus has the potential to provide greater production of milk / ha and per ton DM with respect to hybrid maize.

Keywords: corn; forage; milk production; silage; high valleys of Mexico.

1. Introduction

The cultivation of corn and the production of dairy milk represent two of the main economic activities in Mexico (Reta et al., 2015, Espinoza et al., 2007). According to SAGARPA (2016), there is a population of 2.3 million dairy cows, of which 85% are located on small-scale farms, contributing approximately 70% of the national milk supply per year, with a reported annual production per cow of 5190 L (Posadas et al., 2016). In the same context, the national production of dairy milk for the second quarter of 2017 reached 5670 million liters (SIAP, 2017). In 2016, Mexico imported 209,803 tons of milk powder to cover national supply needs, a number which is expected to increase (Portalechero, 2017).

In 2013, Mexico was identified as one of the countries most affected by climate change. Furthermore, maize production is the main peasant farming activity in Mexico. Nearly 2

2

million peasant producers participate in this activity, and 85 percent have less than 5 ha of land. In Mexico, corn represents the main use crop for the production of dairy milk and human consumption (Jiménez-Leyva et al., 2016), and an undetermined amount is allocated as straw, green fodder, and to a lesser extent for the preparation of silages for cattle feed (Celis-Álvarez et al., 2016; Jiménez-Leyva et al., 2016). According to the SIAP (2016) reports, in Mexico in 2015, an area of 445,775 ha was planted in the rainy season and 161,623 ha in irrigation for fodder maize, with yields of 19.29 and 47.55 ton / ha of dry matter (DM) and green matter (GM), respectively. Given the great heterogeneity of agroclimatic conditions has a negative impacts agricultural-animal production, resulting in a disparity of yields per hectare and per animal, which is why there is a need to optimize the use of forage.

The StAnD (sustainable animal diets) method (Makkar and Ankers, 2014) is a tool that integrates several dimensions of sustainability, including the three P (people, planet and profitability) dimensions, and gives an overall picture of the current state of a production system. The indicators corresponding to each dimension allow for the detection of specific problems or particular limitations that may be addressed in order to improve the sustainability of the system (Makar and Ankers, 2014; FAO, 2014). One indicator of the StAnD method is "do not use cereals in animal diets and improve the use of native resources" (Planet dimension). This study used the StAnD method to evaluate the sustainability of native and hybrid silages in Mexico, and can help to guide agricultural practices and policies in accordance with the economic and environmental performance of different maize production systems. The objective of the present study was to determine the quality and forage yield (ton / ha) of some of the corn silages produced in Mexico and to estimate the potential production of milk with the Milk 2006 program.

3

2.Materials and methods

2.1. Data collection

An information search was carried out focused on collecting studies on corn forage yield and quality produced in the different geographic regions of Mexico, which were grouped into three general zones, taking as a criterion of classification their climatic characteristics (Améndola et al., 2005): 1. northern zone or arid and semi-arid region, composed of the states of Baja California, Baja California Sur, Coahuila, Chihuahua, Durango, Nuevo Leon, San Luis Potosi, Sonora, Tamaulipas and Zacatecas; 2. central zone or integrated temperate region, consisting of the states of Aguascalientes, Mexico City, State of Mexico, Guanajuato, Hidalgo, Jalisco, Michoacán, Morelos, Puebla, Querétaro and Tlaxcala; 3. southern zone or tropical dry and humid region, containing the states of Campeche, Colima, Chiapas, Guerrero, Nayarit, Oaxaca, Quintana Roo, Sinaloa, Tabasco, Veracruz and Yucatan.

The publications were obtained from searches in databases such as Elsevier, Google, SCOPUS, Web of Science and Redalyc. The search strings consisted of terms found in the title, abstract and keywords. The terms used were: "corn"; "silage"; "forage yield"; "chemical composition"; "nutritional value"; "high valleys of Mexico", "Mexico", any plurals of these terms, and combinations of these terms, and thirteen articles were selected (Núñez et al., 2001, Núñez et al., 2003, Peña et al., 2006; Ruiz et al., 2006; Antolín et al., 2009; Anaya et al., 2009; Núñez et al., 2010; Albarrán et al., 2012; Tadeo et al., 2012; Jurado et al., 2014; Morales et al., 2014; Franco et al., 2016; Jiménez et al., 2016).

2.2. Criterion of inclusion

The selection process limited the results to studies published from 2001 to 2016. For inclusion in the final database, the studies should have been done in one of the different geographical regions of the Mexican Republic and also include agronomic and chemical variables such as: dry matter yield (ton / ha), plant density (number of plants / ha), dry matter content (DM), crude protein (CP), neutral detergent fiber (NDF), ash or organic matter (OM), digestibility of dry matter (DMD), neutral detergent fiber digestibility (NDFD), starch and fat content, as well as region of origin and genetic line (native vs. hybrid).

The final database included a total of 144 records, of which 137 were from hybrid maize and seven from native maize. Data were collected from studies in the north and center regions of Mexico without finding information from the southern zone.

2.3. Calculations

The missing values for NDFD were calculated using a regression equation with the data obtained from all the registered works that did not contain this information:

NDFD (%) = 77.96 (± 1.85) + [(NDF %) * (- 0.36 (± 0.95))]

The missing data for starch and fat in those works that did not contain this information were adjusted according to the NRC (2001). The net energy of lactation (NEL, MJ / kg DM), total digestible nutrients (TND), kilograms of milk per ton of dry matter (kg milk / ton DM) and kilograms of milk per hectare were determined (kg milk / ha) using the MILK2006 spreadsheet (Shaver, 2006).

2.4. Statistical analysis

In order to identify differences between maize production systems and their distinct dimensions, Kolmogorov-Smirnov tests were applied to determine if the resulting scores varied significantly with respect to a normal distribution. After the data was determined to have a normal distribution, the datasets were analyzed by a model with a completely randomized design and Tukey's average comparison test ($P<0.05$). These analyses were carried out with the SAS statistical software (Statistical Analysis System, 2004).

Data on dry matter production, chemical composition and milk production of silage were analyzed using a completely randomized design. The information was computed through an analysis of variance with the SAS program (2002), according to the following statistical model:

$Y_{ijk} = \mu + region_i + genetic\ line_j + \square_{ij}$

where: Y_{ijk} = dry matter, chemical composition and milk production, μ = general mean, $region_i$ = effect of the variety (n = 2), genetic line = effect of the method (n = 2) and $\square_{ij}$= random error.

The effects were considered significant if they were lower than $P<0.05$. To determine if there were differences between the effects, the Tukey test was used for multiple comparison of means (Steel and Torrie, 1997).

Subsequently, a Pearson correlation analysis was carried out to estimate the relationship between the variables of dry matter production, chemistry composition and milk production per hectare, using the statistical package Statistical Package for Social Science [SPSS], 2012).

Finally, a multiple linear regression analysis was performed to generate prediction equations for the net energy of lactation (NEL, MJ / kg DM), kilograms of milk per ton of dry matter (kg milk / ton DM) and kilograms of milk per hectare (kg milk / ha), using the correlations with the highest degree of association between the aforementioned variables. In carrying out all the analyses, specialized software was used (Statistical Package for Social Science [SPSS], 2012).

The statistical model used was the following:

$y = (b_0 + b_1 . x_1 + b_2 . x_2 + b_3) + \square_i$

where:

y = NEL, MJ / kg DM, milk kg / ton DM and kg milk / ha, b_0 = intersect of y, b_n = slope of the straight line adjusted to the data, x_n = dependent variables that are included in the model, $\square_i$ = model error.

3. Results

The DM yield per ha (Table 1) was higher (P <0.0001) for the central region (24.8%) than in the northern region, whereas the density of plants in the northern region was higher (P <0.0001) compared to the center. The DMD was four points smaller (P <0.0001) for the center region than the northern region, the CP content was higher (P <0.0001) for the northern region than the center region, and in terms of NEL (Mj / kg DM) and kg of milk per ton / DM there were no differences between regions (P> 0.05). Milk production / ha, however, was higher (P <0.0001) in the central region compared to the northern region. Regarding the variety (Table 2), the forage yield per ha was higher for the hybrids (P = 0.0018) with respect to the native silages, but similar (P> 0.05) in terms of plant density and CP content, NDF, DMD and NDFD. The percentage of DM was higher (P <0.001) for the hybrids with respect to the natives. A tendency (P = 0.07) was observed for the content of NEL and kg milk / ton DM to be higher in the native silages with respect to the hybrids, and also for milk yield, (kg milk/ ha) to be higher in the native silages (P = 0.03) compared to hybrids.

In Table 3 a positive correlation was observed (P <0.01) for DM production and kg milk / ha, and negative relationship (P <0.05) was observed for DM yield, CP content and DMD. Likewise, a positive correlation was observed (P <0.01) for the NDFD and TND, and for the content of NEL (MJ / kg DM) and kg milk / ton DM.

The resulting prediction equations for calculating the NEL (MJ / kg DM), kg milk / ton DM and kg milk / ha are presented in Table 4. The use of two variables explained the greater variation for NEL (MJ / kg DM) and kg milk / ton DM, while for kg milk / ha only one variable was used.

4. Discussion

The differences in DM production, number of plants, CP content and milk production (kg milk / ha) in the two regions studied can be attributed to the degree of maturity reached by the plant at the time of cutting, as well as for the variety of the plant, both of which determine forage yield and milk production per ton of dry matter (Antolin-Domínguez et al., 2009).

In the northern region, fodder maize of tropical or temperate origin is used, which has a smaller harvest cycle, as well as smaller stems and fewer leaves, which decreases DM production, in addition to requiring a greater number of plants to reach an optimum forage yield; however, this increase does not mean a higher production of biomass per unit area (Núñez et al., 2001; Elizondo and Boschini, 2002) as found in the present study, as the native maize is the one that presented a greater amount of DM.

González et al. (2008) and Aragón et al. (2005), mention that in the center of Mexico from 87 to 90% of maize that is sown has a larger stem size, which encouages higher production (ton DM / ha). The altitude of the plant, as well, can influence the increase of milk production / ha (Wu and Roth, 2005), although this type of corn, because of its maturation stage at the time of cutting, has a lower amount of CP (Peña et al., 2002) compared with the maize sown in other latitudes (Ali et al., 2012; Khan et al., 2015), which contains a higher content of CP and NEL at the time of silage.

The forage yield (ton DM / ha) and the DM content were higher in the hybrid corn than the natives silages presented in this study, which may be due to the age of the plant at the time of cutting. Elizondo and Boschini (2002) mention that when comparing hybrid maize against natives with the same age at the time of cutting, the hybrid maize surpasses the dry matter content 400% with respect to the native ones, which coincides with the present study.

Forage yields (ton DM / ha) were higher than those found by Mussadiq et al. (2013) and Cusicanqui and Lauer (1999), who reported 11.7 and 17 tons of DM / ha of hybrid maize respectively, but similar to those of Cox and Cherney (2001), who reported 19.5 ton DM / ha in hybrid maize. Robles et al. (2017) found 14.10 ton DM / ha wich is in the minimum value in the present study. Herrero et al. (2010) and McDermott et al. (2010) mentioned that the integration of animal manure plays an important role in improving the equilibrium of nutrients in the soil and during crop production. Although 87% of farmers apply manure fertilizer, only 12% adequately perform this practice by first composting the manure, while another 50% apply manure after two weeks of drying. The remaining percentage of farmers apply fresh manure (Paulino Flores et al., 2017).

Lasmar de Olveira et al. (2017) in tropical climates (1085 kg milk / ton DM) and Mussadiq et al. (2013), with 1207 kg of milk / ton DM are higher than the present study (499 ±8 kg milk/ ton DM). Cox and Cherney (2001) found a milk yield that varies from 11.3 to 18.5 ton of milk / ha, lower yields than the present study (22.4±0.1 ton of milk/ha). It is also evident that despite this lower yield of DM in native maize compared to hybrid maize, a greater quantity of milk (kg milk / ha) is produced, which is still conserved by small producers and is easily commercialized (Boschini and Elizondo, 2004) in the region. This increase in milk production that occurs in native maize can be explained because the hybrid maize, while presenting a greater amount of forage, decreases the production of ears (Nuñez et al., 2003; Peña et al., 2003), which can decrease the amount of starch in the plant causing lower milk yields per ton DM and kg milk / ha (Ferraretto and Shaver, 2013, Lascano et al., 2016). In this system, the standard native production yield of maize is 18 tons / ha. This relatively low yield renders these enterprises less economically viable compared with other countries, especially considering the low market prices for maize and high dependency of these farmers on government subsidies.

The correlations obtained in this study agree with Shaver and Lauer (2006) and the Milk2006 model. Schwab et al. (2003) mention that the Milk2006 model has the basic concept of a summative energy equation, which is fulfilled in this study, obtaining a significant correlation regarding the concentration of NEL and the estimated production of kg milk / ton DM ($r = 0.99$).

The resulting equations (Table 4) to predict the NEL and kg milk / ton DM were acceptable using only two variables, which may be due to the fact that the two variables used in the MILK2006 model were used, which are calculated according to the variables used in this model (Schwab et al., 2003, Mussadiq et al., 2013). The equation to calculate the milk yield (kg milk/ ha) resulting in this study is similar to that of Mussadiq et al. (2013), who mention that this means of calculating kg milk / ha is a combination of quality and quantity parameters of corn silage according to what is established by the MILK2006 model.

5. Conclusion

The use of native maize in Mexico is a viable alternative for use as a silage in feed for dairy cows, with higher milk production per hectare and per ton of dry matter compared to hybrid maize. Likewise, there is greater milk production / ha in the central region of

10

the country. This circumstance can reinforce the use of local native varieties for their productive characteristics, thus preserving the indigenous biodiversity of corn seeds, the nation's cultural heritage, which would support government involvement in their care. More studies are required to evaluate the chemical composition of corn silage, especially the inclusion of starch, fat and its digestibility for a better approximation.

Acknowledgements

The M in C. Liz Robles was benefited by a grant of the Conacyt during its studies of Doctorate, in the programa de Maestria y Doctorado en Ciencias Agropecuarias y Recursos Naturales, Universidad Autonoma del Estado de Mexico. This project was supported by UAEM 4335/2017.

References

Albarrán, B., García, A., Espinoza, A., Espinosa, E. y Arriaga, C. M., 2012. Maize silage in the dry season for grazing dairy cows in small-scale production systems in Mexico highlands. Indian J. Anim. Res. 46(4), 317-324.

Ali, M., Weisbjerg, M.R., Cone, JW., van Duinkerken, G., Blok, M.C., Bruinenberg, M., Hendriks, W.H.2012. Postruminal degradation of crude protein, neutral detergent fibre and starch of maize and grass silages in dairy cows. Anim. Feed Sci. Technol. 177:172 – 179.

Améndola, R., Castillo, E. y Martínez, P., 2005. Perfiles por país del recurso pastura/forraje. Roma, Italia: ed. FAO.

Anaya-Ortega, J. P., Garduño-Castro, G., Espinoza-Ortega, A., Rojo-Rubio, R. and Arriaga-Jordán, C. M., 2009. Silage from maize (Zea mays), annual ryegrass (Lolium multiflorum) or their mixture in the dry season feeding of grazing dairy cows in small-scale dairy production systems in the highlands of Mexico. Trop. Anim. Health Produ. 41, 607-616.

Antolín-Domínguez, M., Gonzalez-Ronquillo, M., Goñi-Cedeño, S., Domínguez-Vara, I. A., Ariciaga-Gonzalez, C., 2009. Rendimiento y producción de gas in vitro de maíces híbridos conservados por ensilaje o henificado. Téc. Pecu. Méx. 47(4), 413-423.

Aragón, C.F; Taba, S.; Castro, G. H.F., Hernández, C. J.M.; Cabrera, T. J.M., Osorio, A.L.; Dillanés, R.N. 2005. In situ conservation and use of local maize races in Oaxaca, Mexico: A participatory and decentralized approach. In Taba, S. ed. Latin American maize germplasm conservation: regeneration, in situ conservation, core subsets, and prebreeding; In Proceedings of a workshop held at CIMMYT. CIMMYT, Mexico, D. F. 26-38.

Boschini C., Elizondo J.A. 2004. Rendimiento de forraje de dos materiales genéticos de maíz (*Zea mays* L.) sembrados a diferentes distancias de siembra. Agron. Trop. 34:87-92.

Celis-Álvarez, M. D., López- González, F., Martínez-García, C. G., Estrada-Flores, J. G. and Arriaga-Jordán, C. M., 2016. Oat and ryegrass silage for small-scale dairy systems in the highlands of central Mexico. Trop. Anim. Health Prod. 48: 1129-1134.

Cox, W. J. and Cherney, D. J. R., 2001. Row spacing, plant density and nitrogen effects on corn silage. Agron. J. 93: 597-602.

Cusicanqui, J. A. and Lauer, J, G., 1999. Plant density and hybrid influence on corn forage yield and quality. Agron. J. 91: 911-915.

Elizondo, J., C. Boschini. 2002. Producción de forraje con maíz nativo y maíz híbrido. Agron. Mesoam. 13:13-17.

Espinoza-Ortega, A., Espinosa-Ayala, E., Bastida-López, J., Castañeda-Martínez, T. and Arriaga-Jordán, C.M., 2007. Small-scale dairy farming in the highlands of central Mexico: technical and social aspects and their impact on poverty. Exp. Agric. 43, 241-256.

FAO. Towards a concept of Sustainable Animal Diets.; 2014. By Makkar HPS, Ankers P. FAO Anim. Prod. Health Rep. No. 7. ⊠

Ferraretto, L. F., and Shaver, R. D., 2013. Meta-analysis: Effects of corn silage hybrid type on intake, digestion, and milk production by dairy cows. J. Dairy Sci. 96:214.

Franco-Martínez, J. R. P., 2016. Identificación de maíces sobresalientes por su potencial y calidad forrajera en el valle de Toluca-Atlacomulco, Estado de México. Tesis de doctorado. Programa de Ciencias Agropecuarias y Recursos naturales, PCARN. Campus Universitario el Cerrillo, Toluca, Estado de México.

González, H.A.; Vázquez, G, L.M., Sahagún, C.J.; Rodríguez, P.J.E., 2008. Diversidad fenotípica en variedades e híbridos de maíz en el Valle de Toluca-Atlacomulco, México. Rev. Fitotec. Mex. 31(1), 67-76.

Herrero, M., Thornton, P.K., Notenbaert, A.M., Madera, S., Msangi, S., Freeman, H.A., Bossio, D., Dixon, J., Peters, M.,van de Steeg, J., Lynam, J.,Parthasarathy, Rao P.,Macmillan, S., Gerard, B., McDermott, J., Seré, C.,Rosegrant, M., 2010. Smart Investment in the sustainable production of food: review of mixed agricultural and livestock systems. Science. 327(5967), 822-825.

Jiménez-Leyva, D., Romo-Rubio, J., Flores-Aguirre, L., Ortiz-López, B. y Barajas-Cruz, R., 2016. Edad de corte en la composición química del ensilado de maíz blanco asgrow-7573. Abanico Vet. 6(3), 13-23.

Jurado-Guerra, P., Lara-Macías, C. R., y Saucedo-Terán, R. A., 2014. Paquete tecnológico para la producción de maíz forrajero en Chihuahua. Coyoacán, México D. F., ed. Inifap. http://biblioteca.inifap.gob.mx:8080/jspui/bitstream/handle/123456789/4311/010208104500066446_CIRNOC.pdf?sequence=1

Khan, N. A., P. Q. Yu, M. Ali, J. W. Cone, and W. H. Hendriks. 2015. Nutritive value of maize silage in relation to dairy cow performance and milk quality. J. Sci. Food Agric. 95:238–252.

Lasmar de Oliveira, I., Miranda-Lima, L., Rume-Casagrande, D., Stefanelli-Lara, M. A. and Fernandes Bernardes, T., 2017. Nutritive value of corn silage from intensive dairy farms in Brazil. R. Bras. Zootec. 46(6), 494-501.

Lascano, G. J.; Alende, M.; Koch, L. E. and Jenkins, T. C., 2016. Changes in fermentation and biohydrogenation intermediates in continuous cultures fed low and high levels of fat with increasing rates of starch degradability. J. Dairy Sci. 99, 6334-6341

Makkar HPS, Ankers P., 2014. Towards sustainable animal diets:a survey-based study. Anim. Feed Sci. Technol. 198, 309–22. ⊠

McDermott, J.J., Staal, S.J., Freeman, H.A., Herrero, M., Van de Steeg, J.A., 2010. Maintaining the intensification of small-scale livestock systems in the Tropics (El mantenimiento de la intensificacion de los sistemas ganaderos en pequenña escala en los tropicos). Ganad. Cienc. 130, 95e109. http://dx.doi.org/10.1016/j.livsci.2010.02.014.

Morales, R. A., Morales, R. E. J., Franco, M. O., Mariezcurrena, B. D., Estrada, C. G. y Norman, M.T. H., 2014. Densidad de población en maíz, coeficiente de atenuación de luz y rendimiento. Rev. Mex. Cienc. Agric. 8, 1425-1431.

Mussadiq, Z., Gustavsson, A., Geladi, P., Swensson, C. and Hetta, M., 2013. Effects of morphological fractions on estimated milk yields in forage maize depending on growing site and plant maturity. Acta Agric. Scand. Sect. A-Animal science. 63(3), 131-142.

Núñez-Hernández, G., Payan-García, J. A., Pena-Ramos, A., González-Castañeda, F., Ruiz-Barrera, O. y Arzola-Álvarez, C., 2010. Caracterización agronómica y nutricional del forraje de variedades de especies anuales en la región norte de México. Rev. Mex. Cienc. Pecu. 1(2), 85-98.

Núñez-Hernández, G., Contreras-G, E. F. y Faz-Contreras, R., 2003. Características agronómicas y químicas importantes en híbridos de maíz forrajero con alto valor energético. Téc.Pecu. Méx. 41(1), 37-48.

Núñez-Hernández, G., Faz-Contreras, R., Tovas-Gómez, M. R. y Zavala-Gómez, A., 2001. Híbridos de maíz para la producción de forraje con alta digestibilidad en el norte de México. Téc. Pecu. Méx. 39(2). 77-88.

Paulino-Flores, M., Martínez-Campos, A.R., Martínez-Castanñeda, F.A., Lopez-Orona. C.A., Vizcarra-Bordi, I., Munguía, N., 2017. Evaluation of the sustainability of hybrid and native maize production systems. J. Clea. Prod. 150, 287-293.

Peña-Ramos, A., González-Castañeda, F., Núñez-Hernández, G., Tovar-Gómez, Ma. Del R., Preciado-Ortiz, R. E., Torreón-Ibarra, A., Gómez-Montiel, N., Ortega-Corono, A., 2006. Estabilidad del rendimiento y calidad forrajera de híbridos de maíz. Rev. Fitotec. Mex. 29(2), 109-114.

Peña, R.A., Nuñez, H.G., González, C. F., 2003. Importancia de la planta y el elote en poblaciones de maíz para el mejoramiento genético de la calidad forrajera. Téc. Pecu. Méx. 41(1), 63-74.

Peña, R.A., Núñez, H.G., González, C.F. 2002. Potencial forrajero de poblaciones de maíz y relación entre atributos agronómicos con la calidad. Téc. Pecu. Méx. 40(3), 215-228.

Portalechero.com., 2017. México: es el segundo importador de mundial de leche en polvo. https://www.portalechero.com/innovaportal/v/12204/1/innova.front/mexico:es-el-segundo-importador-mundial-de-leche-en-polvo.html (7 de diciembre de 2017).

Posadas-Domínguez, R. R., Callejas-Juárez, N., Arriaga-Jordán, C. M. and Martínez-Castañeda, F.E., 2016. Economic and financial viability of small scale dairy systems in central Mexico: economic scenario 2010-2018. Trop. Anim. Health Prod. 48(8), 1667-1671.

Reta-Sánchez, D. G., Figueroa-Viramontes, U., Serrano-Corona, J.S., Quiroga-Garza, H.M., Gaytan-Mascorro, A. y Cueto-Wong, J. A., 2015. Potencial forrajero y productividad del agua en patrones de cultivos alternos. Rev. Mex. Cien. Pecu. 6(2), 153-170.

Robles-Jiménez, L.E., Ruiz-Prez, J.A., Morales-Osorio, A., Gutiérrez-Martinez, M.G., González-Ronquillo, M. 2017. Producción de forraje, composición química y producción de gas in vitro de maíces híbridos amarillos cultivados en México. Trop. Subtrop. Agroecosyst. 20, 373 – 379.

Ruiz, O., Beltrán, R., Salvador, F., Rubio, H., Grado, A. y Castillo, Y., 2006. Valor nutritivo y rendimiento forrajero de híbridos de maíz para ensilaje. Rev. Cub. Cienc. Agric. 40(1), 91-96.

SAGARPA- Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. 2016. Escenario base 09-18. Proyecciones para el sector agropecuario de México. http://www.sagarpa.gob.mx/agronegocios/Documents/Escenariobase09.pdf

SAS, Statistical Analysis System Institute. (2002). Statistical Analysis System Institute Inc. SAS/STAT User's Guide, Cary, North Carolina, U.S.A.

Shaver, R., 2006. Corn silage evaluation: MILK 2000 challenges and opportunities with MILK 2006. http://www.uwex.edu/ces/dairynutrition/ documents/milk20062.pdf. (12-09-2017).

Shaver, R. D., & Lauer, J. G. (2006). Review of Wisconsin corn silage milk per ton models (Abstr.). J. Dairy Sci. 89, 282–283.

SIAP- Servicio de Información Agroalimentaria y Pesquera. 2016. Anuario estadístico de la producción agrícola. http://nube.siap.gob.mx/cierre_agricola/ (12-09-2017).

SIAP- Servicio de Información Agroalimentaria y Pesquera., 2017. Panorama de la leche en México. Junio 2017. http://infosiap.siap.gob.mx/opt/boletlech/B_leche_%20junio2017.pdf (12-09-2017).

Schwab, E. C., Shaver, R. D., Lauer, J. G. & Coors, J. G., 2003. Estimating silage energy value and milk yield to rank corn hybrids. Anim. Feed Sci. Technol. 109, 1–18.

Statistical Package for Social Science (SPSS)., 2012. SPSS Base 21.0 user's guide. Chicago (IL).

Steel, R.G., Torrie, J.H., 1997. Principles and procedures of statistics a biomedical approach (2nd ed). New York, NY: Mc Graw Hill Book Co. New York, pp 179-180.

Tadeo-Robledo, M., Espinosa-Calderón, A., Zaragoza-Esparza, J., Turrent-Fernández, A., Sierra Macías, M. y Gómez-Montiel, N., 2012. Forraje y grano de híbridos de maíz amarillos para valles altos de México. Agron. Mesoam. 23(3), 281-288.

Wu, Z., Roth G. 2005. Considerations in managing cutting height of corn silage. Extension publication DAS 03-72. The Pennsylvania State University, University Park. p 7.

Table 1. Forage production (ton / ha) density of plants, chemical composition of silage and its potential milk production (kg milk / ton DM and kg milk / ha) of corn silage sown in the central and northern region of Mexico.

	Center region N.40			North region N.120				
Variable	Maximum	Minimum	Average	Maximum	Minimum	Average	SEM	P Value
Forage yield (ton DM/ha)	34.20	9.50	20.73	22.10	9.40	15.58	0.831	0.0001
Plant Density, ha	85000	62500	67062	100000	23000	84745	1834	0.0001
DM%	43.60	11.10	29.03	44.80	18.40	30.21	1.20	0.6096
DMD%	70.30	47.70	63.20	76.10	60.40	67.81	0.99	0.0001
CP%	10.00	4.40	6.84	10.30	6.40	8.06	0.23	0.0001
NDF%	69.90	33.80	56.39	68.00	31.00	56.96	1.67	0.8647
NDFD %	68.40	43.00	57.68	66.80	50.30	57.46	0.78	0.9962
TDN%-MS[1]	72.73	59.42	63.53	71.75	47.14	63.64	0.67	0.4487
NE_L, MJ/KgDM[1]	6.53	5.23	5.61	6.44	4.60	5.65	0.01	0.2614
Kg milk ton/DM[1]	615.54	440.77	492.24	602.94	327.64	495.25	9.15	0.3024
Kg milk/ ha	38829	13888	25644	28093	9153	21131	975.29	0.0001

Table 2. Forage production (ton / ha) density of plants, chemical composition of silages and their potential milk production (kg milk / ton MS and kg milk / ha) of hybrid and native corn silages sown in Mexico

	Native silage N.7			Hybrid silage N.135				
Variable	Maximum	Minimum	Average	Maximum	Minimum	Average	SEM	**P Value**
Forage yield (ton DM/ha)	22.30	14.10	18.34	34.20	9.40	19.23	1.41	0.0018
Plant Density ha	22,500	62,500	65,714	100,000	62,500	80,492	3,112	0.6226
DM%	23.10	17.10	20.95	44.80	11.10	30.34	2.05	0.0001
DMD %	69.50	55.30	65.56	78.30	47.70	66.56	1.68	0.1144
CP%	9.50	4.70	6.97	10.30	4.40	7.75	0.435	0.7266
NDF%	61.10	36.30	52.56	69.90	31.00	57.02	2.84	0.1261
NDFD %	67.70	52.40	58.72	68.40	43.00	57.46	1.33	0.3715
TDN-DM %[1]	69.81	60.66	65.33	72.73	47.14	63.52	1.26	0.1058
NEL, MJ/KgDM[1]	6.11	5.44	5.82	6.53	4.60	5.65	0.026	0.0700
Kg milk ton/DM[1]	568.10	464.28	516.84	615.54	327.64	493.24	15.52	0.0733
Kg milk/ ha [1]	27,442	15,499	22,471	38,829	9,153.73	22,399	1,654.97	0.0307

DM = dry matter content, DMD = digestibility of dry matter, CP = crude protein, NDF = neutral detergent fiber, NDFD = neutral detergent fiber digestibility, TND = total digestible nutrients NEL = net energy for lactation (Mj / kg DM), kg milk / Ton DM = kilograms of milk per ton of dry matter, Kg Milk / ha = kilograms of milk per hectare.

DM = dry matter content, DMD = digestibility of dry matter, CP = crude protein, NDF = neutral detergent fiber, NDFD = neutral detergent fiber digestibility, TND = total digestible nutrients NEL = net energy for lactation (Mj / kg DM), kg milk / Ton DM = kilograms of milk per ton of dry matter, Kg Milk / ha = kilograms of milk per hectare.

Table 3. Correlation matrix between forage production and plant density by ha compared to its chemical composition of silage and its potential milk production (kg) per ton DM and kg milk / ha.

Variables	Plant density, ha	DM%	DMD %	CP%	NDF%	NDFD%	TDN %-DM	NELMJ / Kg DM	Kg milk/ ton DM	Kg milk/ ha
Forage yield (ton DM/ha)	-0.308**	0.453**	0.380**	0.352**	0.183*	-0.143	-0.115	-0.160	-0.153	0.940**
Plant density ha		0.149	0.570**	0.336**	0.045	0.005	-0.112	-0.131	-0.119	-0.347**
DM%			-0.155	0.114	-0.114	0.084	-0.157	-0.259**	-0.228**	0.365**
DMD%				0.116	-0.169*	0.200*	0.258**	0.289**	0.282**	-0.281**
CP%					0.373**	0.302**	0.273**	0.251**	0.264**	-0.276**
NDF%						-0.769**	-0.605**	-0.538**	-0.578**	0.001
NDFD%							0.598**	0.460**	0.525**	0.022
TDN-DM%								0.967**	0.988**	0.210*
NEL,MJ / Kg DM									0.994**	0.176*
Kg milk/ ton DM										0.181*

* P <0.05, ** P <0.001, *** P <0.001

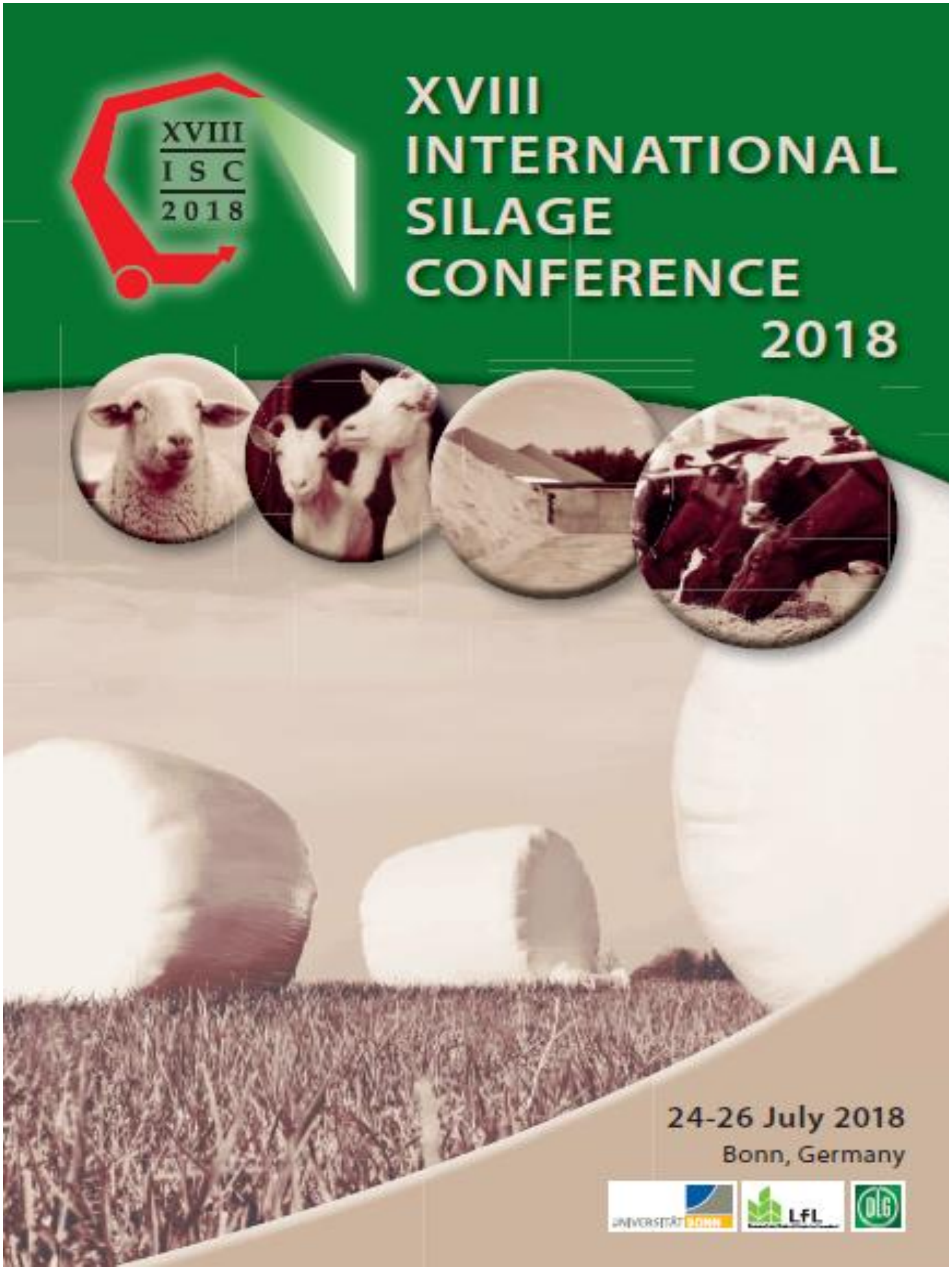
DM = dry matter content, DMD = Digestibility of dry matter, CP = crude Protein, NDF = Neutral Detergent Fiber, NDFD = neutral detergent fiber digestibility, TND = Total digestible nutrients, NEL = Net Energy for Lactation (Mj / kg DM), kg milk / Ton DM = kilograms of milk per ton of dry matter, Kg Milk / ha = kilograms of milk per hectare.

Table 4. Equations to estimate (y = a + bx 1 + bx 2) the NEL (Mj / kg DM), Kg milk / ton DM and kg milk / ha, using maize silage sown in Mexico.

Y	Equation	r^2	P Value
NE_L (MJ/kg DM)	Y = 0.097 (±0.025) +0.023 (±0.001) * (TDN) -0.004 (±0.0001) *(NDFD %)	0.96	0.001
Kg milk/ton DM	Y= -306.06 (±5.75) +550.31 (±4.35) * (NE_L, MJ/kgMS) + 1.01 (±0.08) * (NDFD %)	0.99	0.001
Kg milk/ha	Y = 2007.62 (±638.07) + 1062.67 (±32.48) * (Forage yield (ton DM/ha))	0.88	0.001

DM = dry matter content, NDFD = neutral detergent fiber digestibility, TND = Total digestible nutrients, NEL = Net Energy for Lactation (Mj / kg DM), kg milk / Ton DM = kilograms of milk per ton of dry matter, Kg Milk / ha = kilograms of milk per hectare.

11.2. Comunicación aceptada y publicada en: "XVIII International Silage Conference 2018"



Proceedings of the
XVIII International Silage Conference

XVIII
ISC
2018

24-26 July 2018

Bonn, Germany

Edited by

K. Gerlach and K.-H. Südekum

UNIVERSITÄT BONN

LfL

bavarian state research center for agriculture

DLG

Committees and Reviewers

Organising Committee

Christian Böttger
Wolfgang Büscher
Katrin Gerlach
Nina Gresner
Klaus Hünting
Annette Jilg
Detlef Kampf
Ewald Kramer
Daniela Latzke
Bernd Lengers
Gerd-Christian Maack
Siriwan Martens
Barbara Misthilger
Hansjörg Nußbaum
Mariana Schneider
Hubert Spiekers
Walter Staudacher
Karl-Heinz Südekum
Olaf Steinhöfel
Johannes Thaysen
Kirsten Weiß

Scientific Committee

Wolfgang Büscher, University of Bonn, Germany
Katrin Gerlach, University of Bonn, Germany
Gerd-Christian Maack, University of Bonn, Germany
Hubert Spiekers, Bavarian State Research Center for Agriculture, Poing, Germany
Karl-Heinz Südekum, University of Bonn, Germany
Kirsten Weiß, Humboldt Universität zu Berlin, Germany

Reviewers

Uchenna Young Anele, North Carolina A&T State University, Greensboro, NC, USA
Horst Uwe Auerbach, International Silage Consultancy, Wettin-Löbejün, Germany
Thiago Bernardes, Federal University of Lavras, Brazil
Christian Böttger, University of Bonn, Germany
Katrin Gerlach, University of Bonn, Germany
Martin Gierus, University of Natural Resources and Life Sciences, Vienna, Austria
Nina Gresner, University of Bonn, Germany
Sandra Hoedtke, LMS LUFA Rostock, Germany
Kenneth F. Kalscheur, U. S. Dairy Forage Research Center, Madison, WI, USA
Sophie Krizsan, Swedish University of Agricultural Sciences, Umeå, Sweden
Gerd-Christian Maack, University of Bonn, Germany
Siriwan Martens, Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie, Köllitsch, Germany
Richard Muck, U. S. Dairy Forage Research Center, Madison, WI, USA
Elisabet Nadeau, Swedish University of Agricultural Sciences, Skara, Sweden
Åshild T. Randby, Norwegian University of Life Sciences, Ås, Norway
Marketta Rinne, Natural Resources Institute Finland, Jokioinen, Finland
Hans Schenkel, University of Hohenheim, Stuttgart, Germany
Hubert Spiekers, Bavarian State Research Center for Agriculture, Poing, Germany
Håvard Steinshamn, Norwegian Institute of Bioeconomy Research, Tingvoll, Norway
Karl-Heinz Südekum, University of Bonn, Germany
Torsten Thünen, Federal Research Centre for Cultivated Plants, Braunschweig, Germany
Kirsten Weiß, Humboldt Universität zu Berlin, Germany
Roger Wilkins, UK
Ueli Wyss, Agroscope, Posieux, Switzerland

Technical Editing: Susanne Kirchhof
Cover Design and Printing: DundZ GmbH, Am Weißen Kreuz 1, 53498 Bad Breisig
Printed in: Germany
Printing year: 2018
ISBN 978-3-86972-044-9

Welcome Letter

Distinguished Delegates, Ladies and Gentlemen, Dear Colleagues and Friends,

It gives me immense pleasure to extend to you all a very warm welcome on behalf of the Organising Committee of the XVIII International Silage Conference (XVIII ISC 2018) and to say how grateful we are to the members of the International Silage Conference Continuation Group who have accepted our invitation to host this conference for the first time in Germany, here in Bonn. It is an opportune time to renew and intensify contacts and discuss problems of mutual interest with delegates from countries all over the world.

It is gratifying to note that the agenda of the conference covers a wide range of very interesting items relating to the science of silage production and utilization. Silage production will remain a key part in animal production systems across tropical, subtropical and temperate regions. This demands continuing approaches for production of high quality silages involving improvements in management practise to minimise losses and maximise the preservation of the inherent feeding value of the parent crop. Fermented substrates other than silage for ruminants also play a more prominent role nowadays and we are pleased to see that this is also reflected in contributions to this conference. No matter how much we can do by ourselves on the national level, whether it be research, development or extension, it is never enough. In a spirit of true cooperation, we must join in action-oriented efforts to address the challenges and solve the problems that beset plant materials between harvest and utilisation by animals and people.

Generous sponsorships from many industrial companies have recognized that the XVIII ISC 2018 is an important venue to present and discuss scientific and technological progress in silage research across the world. Our Organising Committee members are committed to provide maximum hospitality. Please feel free to ask questions to committee members. We are here to serve you. Enjoy your participation in the XVIII ISC 2018.

In conclusion, I wish you every success in interchange of ideas and a very pleasant stay in Germany.

On behalf of the Organising Committee

Karl-Heinz Südekum

CONTENTS

Advances in Silage Research

Contents

XVIII International Silage Conference

Miscellaneous

Silage Additives

Contents

Contents

Contents

XVIII International Silage Conference

Contents

XVIII International Silage Conference

Contents

XVIII International Silage Conference

Statistics and Experimental Design

List of Authors

Corn silage (native vs. hybrid varieties) as forage to evaluate potential milk yield production in Mexico

M.R. Davila[1,3], L.E.R. Jimenez[2,3], R Montes de Oca[2], J.O. Avalos[2], A.J.C. Canul[4], M.G. Ronquillo[2*]

[1]Instituto en Ciencias Agropecuarias y Recursos Naturales, Universidad Autonoma del Estado de México, Mexico

[2]Facultad de Medicina Veterinaria y Zootecnia, Departamento de Produccion Animal, Universidad Autonoma del Estado de México, Mexico, mrg@uaemex.mx

[3]Programa de Maestria y Doctorado en Ciencias Agropecuarias y Recursos Naturales, UAEM-Mexico

[4]División Académica de Ciencias Agropecuarias, Universidad Juárez Autónoma de Tabasco. Mexico

Keywords: Corn silage, milk yield, Mexico

Introduction Corn forage and milk yield production represent two of the main economic activities in Mexico (Reta et al. 2015). In the case of the cultivation of hybrid maize, greater emphasis has been given to the yield of forage per unit area, than to the nutritional quality, while native maize has greater advantages than hybrid maize as it is a rustic crop that requires low level of inputs such as fertilizers and pesticides.The objective of the present study was to determine the quality and forage yield (ton / ha) of corn silages produced in Mexico, as well as to estimate the potential production of milk with the Milk 2006 program.

Materials and Methods A search was made of studies focusing on the forage yield (ton / ha), density (number of plants / ha) and chemical composition, Dry matter (DM), Organic matter (OM), Crude protein (CP), Neutral detergent fiber (NDF), starch, fat, DM digestibility and NDF digestibility of corn silage produced in Mexico, according to its genetic line (native vs. hybrid). The net energy of lactation (NEL, MJ/kg DM), kilograms of milk per ton of dry matter (kg milk / ton DM) and kilograms of milk per hectare (kg milk / ha) were determined using the MILK2006 spreadsheet (Shaver 2006). The publications were obtained from searches in databases such as Elsevier, Google, SCOPUS and Web of Science. Using the terms "corn silage", "production", "Mexico" and "milk", a total of 14 articles and 144 studies from 2001 to 2016 were obtained. A completely randomized design was used to consider the genetic line variables (native vs. hybrid), and a correlation analysis was performed. The effects were considered significant ($P < 0.05$), using the Tukey test for comparison of means.

Results Forage yield per ha was higher for the hybrids ($P < 0.001$) compared to the native silages, and the two were similar ($P > 0.05$) in terms of density of plants and their content of CP, NDF and DM and NDF digestibility. A trend ($P = 0.07$) was observed of NEL and kg milk / ton DM being higher in native's silages than in hybrid silages; native silages were higher ($P = 0.03$) with respect to the hybrid silages in milk yield kg / ha. A positive correlation was observed ($P < 0.01$) for forage production and kg milk / ha, and Total Digestible Nutrients (TDN / kg DM)($P < 0.01$) with respect to the content of NEL (MJ / kg DM) and kg milk / ton DM.

Discussion The forage yield (ton DM / ha) and the % DM were higher in the hybrid maize with respect to the native silages presented in this study. This may be due to the plant density is 22% higher in hybrid maize at the time of cutting. Also, Elizondo and Boschini (2002) mention that when comparing hybrid maize against native with equal age at time of cutting, the hybrid maize surpasses the dry matter content by 400% with respect to the native silages, probably because some hybrids are early mature varieties. In addition, the increase in milk production that occurs with native maize can be explained because hybrid maize with a greater amount of forage yield evidences decreased ear production (Nuñes et al. 2003), which can decrease the amount of starch in the plant, having lower NEl causing lower milk yields per ton DM and kg milk / ha (Ferraretto and Shaver 2013; Lascano et al. 2016). The correlations obtained in this study agree with those of Shaver and Lauer (2006). Schwab et al. (2003) mentions that the Milk2006 spreadsheet model has the basic concept of a summative energy equation, which coincides in this work, obtaining a significant correlation in terms of NEL concentration and the estimated production of kg milk / ton DM (r = 0.99).

Conclusions The use of native corn silage has a greater potential for milk production / ha and milk yield/ ton DM compared to hybrid silage produced in Mexico probably by their late maturity stage. The conservation of native genetic resources such as corn is thus important in order to maintain sustainable forage resources.

Table 1. Forage production (ton / ha), plant density, chemical composition of the silage and the potential milk production (kg milk / ton DM and kg milk / ha) of hybrid and native corn silages sown in Mexico.

	Native silage	Hybrid silage		
	Mean	Mean	SEM	P-value
Forage Yield (DM/ ha)	18.34^{b}	19.23^{a}	1.41	0.0018
Density (plants/ha)	65714.28	80492.59	3112	0.6226
DM %	20.95	30.34	2.05	0.0001
DMd %	65.56	66.56	1.68	0.1144
CP%	6.97	7.75	0.435	0.7266
NDF %	52.56	57.02	2.84	0.1261
NDFd %	58.72	57.46	1.33	0.3715
TDN-DM %	65.33	63.52	1.26	0.1058
NEL MJ/kgDM	5.82	5.65	0.026	0.0700
Kg Milk/ton DM	516.84	493.24	15.52	0.0733
Kg Milk/ ha	22471^{a}	22399^{b}	1654.97	0.0307

DM = dry matter content, DMd = dry matter digestibility, CP = crude protein, NDF = neutral detergent fiber, NDFd = neutral detergent fiber digestibility, TDN = total digestible nutrients, NEL = net energy for lactation (MJ / kg DM), kg milk / ton DM = kilograms of milk per ton of dry matter, Kg milk / ha = kilograms of milk per hectare.

References

Elizondo, J. & Boschini, C. (2002) Producción de forraje con maíz criollo y maíz híbrido. Agronomía Mesoamericana, 13, 13-17.

Ferraretto, L.F. & Shaver, R.D. (2013) Meta-analysis: Effects of corn silage hybrid type on intake, digestion, and milk production by dairy cows. Journal of Dairy Science, 96, 214.

Lascano, G.J., Alende, M., Koch, L.E. & Jenkins, T.C. (2016) Changes in fermentation and biohydrogenation intermediates in continuous cultures fed low and high levels of fat with increasing rates of starch degradability. Journal of Dairy Science, 99, 6334-6341.

Núñez-Hernández, G., Contreras-G, E.F. & Faz-Contreras, R. (2003) Important agronomic and chemical characteristics in high energy hybrid forage corns. Técnica Pecuaria en México, 41(1), 37-48.

Reta-Sánchez, D.G., Figueroa-Viramontes, U., Serrano-Corona, J.S., Quiroga-Garza, H.M., Gaytan-Mascorro, A. & Cueto-Wong, J. A. (2015) Forage potential and water productivity in alternative cropping patterns. Revista Mexicana de Ciencias Pecuarias, 6(2), 153-170.

Schwab, E.C., Shaver, R.D., Lauer, J.G. & Coors, J.G. (2003) Estimating silage energy value and milk yield to rank corn hybrids. Animal Feed Science and Technology, 109, 1-18.

Shaver, R. (2006) Corn silage evaluation: MILK 2000 challenges and opportunities with MILK 2006. http://www.uwex.edu/ces/dairynutrition/ documents/milk20062.pdf. 12-09-2017.

Shaver, R.D. & Lauer, J.G. (2006) Review of Wisconsin corn silage milk per ton models (Abstr.). Journal of Dairy Science, 89, 282-283.

Relationship of the chemical composition of corn silage to milk production

L.E.R. Jiménez[1], M.R. Davila[2], J.O. Avalos[1], O.A.C. Ortega[1], C.P. Riocerezo[3], M.G. Ronquillo[1*]

[1] Facultad de Medicina Veterinaria y Zootecnia, Departamento de Produccion Animal, Universidad Autonoma del Estado de México, México. *mrg@uaemex.mx

[2] Instituto en Ciencias Agropecuarias y Recursos Naturales, Universidad Autonoma del Estado de México, México.

[3] Departamento de Construcción y Agronomia, Facultad de Ciencias Agrarias y Ambientales, Universidad de Salamanca, Spain

Keywords: corn silage, milk yield, Mexico

Introduction In 2013, Mexico was identified as one of the countries most affected by climate variability. Such variability can have a negative impact on maize production, which is the main peasant farming activity in Mexico, practiced by nearly 2 million farmers, 85% of whom have less than 5 ha of land. To optimize land use in this precarious situation, choice of appropriate corn silage is vital – but is complicated by the lack of information on corn silage and parameters of milk production. The objective of the present study was to characterize corn silage produced in Mexico according to chemical composition, forage yield (ton / ha), as well as potential milk production.

Materials and Methods A search was made for studies related to corn forage yield (ton / ha), density (number of plants / ha) and chemical composition (dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), nonfibrous carbohydrates (NFC), starch, fat, DM digestibility, NDF digestibility) of corn silage produced in Mexico. The total digestible nutrients (TDN), net energy of lactation (NEL Mcal / kg DM), kilograms of milk per ton of silage as dry matter (kg milk / ton DM) and kilograms of milk per hectare of forage silage (kg milk / ha) were determined using the spreadsheet MILK2006 (Shaver 2006). The publications were obtained from searches in databases such as Elsevier, Google, SCOPUS and Web of Science, using the terms "corn silage", "production", "Mexico" and "milk", selecting a total of 14 articles and 144 studies from the years 2001 to 2016. A cluster analysis (CL) was carried out using the Proc Cluster procedure to sort the corn silage according to its chemical and productive characteristics.

Results and Discussion Six groups (CL) of corn silage were obtained. The first group (CL1) was made up of those with greater DMd%, CP%, NDFd%, NFC%, TDN, NEL and kg milk/ ton DM, the second (CL2) of those with the highest CP content, the third (CL3) of those with the highest plant density (number plants/ha), NDF% and the lowest NFCS, TND, NEL, kg milk/ton DM and kg milk/ha, the fourth (CL4) was made up of highest NDF% and OM% content, the fifth (CL5) had higher forage yield (ton DM / ha), DM% content and kg milk / ha, and the sixth (CL6) had higher DM digestibility and the lowest OM% content.The group that produced the highest milk production (kg milk / ton DM) was the one with the highest NDF digestibility and NFCS. This may be because one of the primary factors that determine the nutritional quality of silage is the digestibility of NDF (Khan et al. 2015). Dairy cows also require forage fiber in their diet to maintain rumen function and maximize milk production; however, the excess NDF limits the dry matter intake (CL3 and CL4) due to its contribution to rumen filling (Krämer-Schmid et al. 2016) and forage degradation. In the same way, several works have shown that when the percentage of dry matter of silage maize increases from 25 to 30%, the increase in intake and milk production is higher (Khan et al. 2015). This increase is not only related to the percentage of DM and intake, but also to the increase in nutritional value due to the higher grain content. The high concentration of NEL and CP content stimulates the production of microbial protein in the rumen, increasing the production and concentration of milk protein (Ferraretto et al. 2013; Lascano et al. 2016) and milk yield (kg milk/ton DM); this effect can be seen in CL1. The highest milk yield (kg milk/ha) corresponds to the highest forage DM yield and DM% content which, in spite of the low TDN and NEL, produce more milk/ha derived from this higher DM yield.

Table 1. Corn forage production (DM yield, ton / ha), plant density (plants/ha), chemical composition (%) of the silage and its potential milk production (kg milk / ton DM and kg milk / ha) of corn silages sown in Mexico.

Variables	CL1	CL2	CL3	CL4	CL5	CL6
DM yield	15.6	18.7	17.4	21.4	27.7	20.1
Plant density	82600	80280	92400	62500	70000	69500
DM, %	29.6	29.8	30.2	25.4	40.0	22.1
DMd, %	70.5	67.0	68.8	62.7	58.9	64.3
CP, %	8.6	8.2	7.6	5.2	7.9	6.8
NDF, %	40.2	56.5	62.8	61.1	56.9	54.9
NDFd, %	64.9	57.6	55.4	55.0	57.5	57.5
NFC, %	40.8	24.9	19.2	24.2	24.8	25.7
OM, %	93.5	93.6	93.5	94.8	93.5	91.7
Fat, %	4.2	4.2	4.2	4.2	4.2	4.2
Starch, %	22.8	23.0	23.0	23.0	23.1	23.1
TDN, %	68.1	65.1	60.1	62.9	61.8	63.6
NEL(MJ/kgDM)	1.43	1.38	1.27	1.34	1.29	1.34
Kg milk/ tonDM	546	514	451	489	465	493
Kg milk/ ha	20131	22702	18867	24831	30503	23397

DM = dry matter content, DMd = dry matter digestibility, CP = crude protein, NDF = neutral detergent fiber, NDFd = neutral detergent fiber digestibility, NFC = nonfibrous carbohydrates, OM = organic matter, TND = total digestible nutrients, NEL = net energy for lactation (MJ / kg DM), kg milk / ton DM = kilograms of milk per ton of dry matter, Kg milk / ha = kilograms of milk per hectare

Conclusions The CL1 corn silage in Mexico presents the highest DM digestibility and NEL, producing more milk (kg milk / ton DM); however, the best option is the silage that has a higher forage yield (ton DM / ha) and more than 35% DM (CL5), since this produces more kg milk / ha.

References

Ferraretto, L.F., Crump, P.M, and Shaver, R.D. (2013) Effect of cereal grain type and corn grain harvesting and processing methods on intake, digestion, and milk production by dairy cows through a meta-analysis. Journal of Dairy Science, 96, 533-550.

Khan, N.A., Yu, P.Q., Ali, M., Cone, J.W. & Hendriks W.H. (2015) Nutritive value of maize silage in relation to dairy cow performance and milk quality. Journal Science Food Agriculture. 95, 238-252.

Krämer-Schmid, M., Lund, P.& Weisbjerg, M.R. (2016) Importance of NDF digestibility of whole crop maize silage for dry matter intake and milk production in dairy cows. Animal Feed Science and Technology, 219, 68-76.

Lascano, G.J., Alende, M., Koch, L.E. & Jenkins, T.C. (2016) Changes in fermentation and biohydrogenation intermediates in continuous cultures fed low and high levels of fat with increasing rates of starch degradability. Journal of Dairy Science, 99, 6334-6341.

Shaver, R. (2006) Corn silage evaluation: MILK 2000 challenges and opportunities with MILK 2006. http://www.uwex.edu/ces/dairynutrition/documents/milk20062.pdf. 12-09-2017.