UNIVERSIDAD AUTÓNOMA DE BAJA CALIFORNIA

Instituto de Ciencias Agrícolas

Instituto en Investigaciones en Ciencias Veterinarias

VALORACIÓN NUTRIMENTAL DE LOS GRANOS SECOS DE DESTILERÍA CON SOLUBLES (DDGS) UTILIZADOS EN DIETAS DE FINALIZACIÓN PARA OVINOS DE PELO: DIGESTIÓN DE NUTRIENTES Y FUNCIÓN RUMINAL, COMPORTAMIENTO PRODUCTIVO Y CORTES PRIMARIOS

TESIS

PARA OBTENER EL GRADO DE:

DOCTOR EN CIENCIAS AGROPECUARIAS

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Mexicali, Baja California. **Enero, 2013**

Ésta tesis se realizó bajo la dirección del Consejo Particular indicado, ha sido aprobada por el mismo y aceptada como requisito para la obtención del grado de:

Doctor en Ciencias Agropecuarias

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DEDICATORIA

A DIOS.-

Esta tesis se la dedico a mi Dios quién supo guiarme por el buen camino, darme fuerzas para seguir adelante y no desmayar en los problemas que se presentaban, enseñándome a encarar las adversidades sin perder nunca la dignidad ni desfallecer en el intento.

A MIS PADRES Y HERMANO.-

Dedico este proyecto a mis padres. Quienes a lo largo de mi vida han velado por mi bienestar y educación siendo mi apoyo en todo momento. Depositando su entera confianza en cada reto que se me presentaba sin dudar ni un solo momento en mi capacidad. Los amo con mi vida. A mi hermano que es mi compañero de vida y parte de mi corazón, que siempre ha estado conmigo en muchas etapas de mi vida; cómplice y amigo, este logro también es tuyo.

A MI FAMILIA.-

Por la confianza depositada en mí y por todos los momentos y fechas importantes que no he podido estar a su lado. Gracias por ser parte de mi vida. Dios los bendiga, les de salud y mucha vida para poder retribuirles un poco de lo que me han dado. Los amo, para ustedes es este logro y todos los que nos faltan por alcanzar.

Se la dedico con mucho cariño a Carlos Raúl Rivera Méndez, por ser mi gran amigo y compañero agradeciendo todo tu tiempo y confianza depositada en mí, pero sobre todo gracias por tu cariño y todo lo que juntos hemos aprendido. No se ama a quien no se admira.

¡Escribir la dedicatoria para tesis es como repasar una película para tu memoria!

AGRADECIMIENTOS

A DIOS.-

Por darme la oportunidad de vivir y por estar conmigo en cada paso que doy, por fortalecer mi corazón e iluminar mi mente y por haber puesto en mi camino a aquellas personas que han sido mi soporte y compañía durante todo el periodo de estudio.

A LAS INSTITUCIONES.-

Agradezco infinitamente a CONACYT y al programa “Formación de Doctores Jóvenes”-Sinaloa por su invaluable apoyo que ambos me brindaron durante todo tiempo que duró el posgrado. Así como también al Instituto en Ciencias Agrícolas – UABC, por la oportunidad de ser parte del programa doctoral y culminar mis estudios.

Al Instituto de Investigación en Ciencias Veterinarias y la Facultad de Medicina Veterinaria y Zootecnia-UAS, por brindarme las instalaciones para la realización de los proyectos y estudios. Gracias por la ayuda y confianza en mí depositada.

A MIS MAESTROS.-

Para ustedes todo mi respeto y admiración, les agradezco la oportunidad de estar aquí y por creer en mí. Pero sobre todo les doy gracias por la tolerancia y enseñanzas, que a pesar que caí varias ocasiones siempre me tendieron la mano para poder culminar mis estudios; **Dr. Alejandro Plascencia Jorquera, Dr. Alfredo Estrada Angulo, Dr. Francisco Gerardo Ríos Rincón, Dr. Alberto Barreras Serrano, Dr. José Fernando Calderón y Cortés y Mc. Ma. Alejandra López Soto.** Gracias y que Dios los Bendiga.

Agradezco también la ayuda del personal administrativo que me brindaron la atención y permitieron que la realización de mi posgrado y proyectos fuera de la manera más eficiente; Sandra Rojas e Isidro López, muchas gracias.

A MIS QUERIDOS AMIGOS.-

Dicen que la familia que Dios nos da la oportunidad de elegir libremente, son los AMIGOS. A ustedes les agradezco con todo mi corazón, todo el tiempo que me han acompañado y son parte fundamental de esta etapa. Han sido confidentes, cómplices, colegas, me ayudaron físico y emocionalmente pero sobre todo han sido mis compañeros de vida. No es necesario enlistarlos a todos porque estoy segura que saben quiénes son. Gracias y además de ser parte de mi familia son parte de mi corazón. Toda la suerte y éxito para ustedes.

"Lo importante en la vida no es el triunfo sino la lucha. Lo esencial no es haber vencido, sino haber luchado bien."

(Barón Pierre de Coubertin)

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Durante el proceso de producción de los granos secos de destilería con solubles (DDGS), la fracción proteína, minerales, grasa y fibra se concentran tres veces en los co-productos comparándolos con el maíz; por lo tanto, los DDGS contienen aproximadamente 30% de PC (73% de proteína no degradable en rumen, UIP), 40% de FDN y 11% de grasa (NRC, 2007) y generalmente su precio en el mercado es menor al del maíz (USDA, 2012).

La creciente oferta de DDGS probablemente disminuirá su costo como ingrediente para la alimentación, haciéndolo favorable para el uso como proteína y fuente energética en la industria de producción ganadera. El alto potencial del valor nutricional de los DDGS puede ser utilizado para remplazar a los granos (Klopfenstein et al., 2008) o a los granos más una fuente proteica (Depenbusch et al., 2008) en dietas de finalización para ganado de engorda. Sin embargo, aparentemente el valor nutricional del DDGS varía dependiendo del nivel de inclusión (Uwituze et al., 2010) o de la fracción del ingrediente que este remplazando. (Dicostanzo y Wright, 2012). Históricamente los DDGS han sido utilizados en la alimentación de ganado, cerdos y aves (Rosentrater, 2012). Aun y cuando los DDGS son un ingrediente apropiado para la alimentación de corderos, el valor nutricional de este co-producto en dietas de finalización no ha sido bien definido. Por lo anterior se realizaron dos experimentos con la finalidad de determinar el valor alimenticio de los DDGS incluidos como sustituto de maíz o de maíz y soya en dietas de finalización para ovinos. En el primer experimento se evaluó en ovinos canulados el efecto de la utilización de niveles crecientes de DDGS (0, 10, 20 y 30%) en sustitución del maíz sobre las características de digestión de nutrimentos y la energía digestible de la dieta, mientras que en el segundo experimento se evaluaron niveles crecientes de DDGS (0, 15, 30 y 45%) en sustitución parcial en diferentes proporciones de maíz y pasta de soya sobre el comportamiento productivo, la eficiencia en la utilización de la energía de la dieta y las características de la canal y masa visceral. El sustituir DDGS por maíz hasta un nivel de 30% aumentó el flujo de lípidos, FDN y de N a duodeno. La sustitución del maíz con DDGS incrementó (componente cuadrático) la digestión ruminal de la FDN pero disminuyó linealmente la digestibilidad de la MO. A nivel de tracto total, la digestión del N se incrementó linealmente a medida que se incrementó la participación de los DDGS en la dieta, pero tendió (efecto lineal, P= 0.08) a disminuir la digestibilidad de la MO y la energía bruta. Sin embargo, la concentración de la ED (Mcal/kg) no fue afectada. En el segundo experimento, la sustitución del maíz y soya por DDGS incrementó (componente lineal, P= 0.04) el peso final, la ganancia diaria pero la eficiencia alimenticia, la energía de la dieta o el coeficiente de consumo observado/esperado no fue afectado (P≥0.33). La inclusión de DDGS no afectó el rendimiento de la canal o la grasa de cobertura, pero disminuyó el área del ojo de la costilla e incrementó la grasa pélvica-renal-cardíaca. El efecto de sustituir el maíz y la soya por niveles crecientes de DDGS no afectó el rendimiento al corte o la masa visceral. La energía neta (MJ/kg) estimada de los DDGS resultó en 9.79, 9.62 y 9.50 para la sustitución de 15, 30 y 45% respectivamente. Para ovinos en finalización, los DDGS son un sustituto adecuado tanto para el maíz como en la sustitución de maíz y soya. Sin embargo, a un nivel alto de inclusión (>30%) tiende a disminuir el área del ojo de la costilla y a aumentar la grasa visceral. El valor energético de los DDGS puede ser considerado similar al valor energético del maíz cuando se sustituye hasta un 30% en las dietas de finalización para ovinos.

ABSTRACT

During the production process of dry distillers grain with solubles (DDGS), protein, minerals, fat and fiber are concentrated three-fold as co-products when compared with corn. Therefore, DDGS contains approximately 30% CP (73% ruminal undegradable intake protein, UIP), 40% NDF and 11% fat (NRC, 2007), and often costs less than corn (USDA, 2012). The growing supply of DDGS is likely to lower the cost of the feed ingredient, making it more favorable for use as a protein and energy source in the livestock industry. The high potential of the nutritional value of DDGS can be useful for replacing grains (Klopfenstein et al., 2008) or grains plus proteins sources (Depenbusch et al., 2008) in growing-finishing diets of beef cattle. However, it appeared that the feed value of DDGS may vary by level of inclusion (Uwituze et al., 2010) as well as the strategy of ingredients that replaces (Dicostanzo and Wright, 2012). Historically, DDGS has primarily been feed to beef and dairy cattle, swine and poultry (Rosentrater, 2012). Even though DDGS should be appropriate as a feed ingredient for lambs, the feeding value of DDGS in finishing diets fed to lambs is well not defined. For the above, two experiments were conducted to evaluate the feeding value of DDGS as substitute of corn or corn plus soybean meal in finishing diet to lambs. In the first experiment, a cannulated lambs were used to evaluate increasing levels (0, 10, 20 and 30%) of DDGS in substitution of dry-rolled corn grain on digestive function and dietary energy, while in the second experiment increasing levels (0, 15, 30 and 45%) of DDGS as substitute of corn plus soybean meal was evaluated on growth-performance, dietary energetic and carcass characteristics. Replacing corn with DDGS increased (linear) duodenal flow of lipids, neutral detergent fiber (NDF) and N. Substitution of DR corn with DDGS increased ruminal NDF digestion (quadratic effect), but decreased ruminal OM digestion (linear effect). Total tract digestion of N increased (linear) as the DDGS level increase, but DDGS substitution tended (P = 0.08) to decrease total tract digestion of OM and digestion of gross energy. However, it did not affect the dietary digestible energy (Mcal/kg). In the second experiment, DDGS substitution improved (linear *P*= 0.04) final weight and average daily gain, but as a consequence of a tendency (*P* =0.06) to increase dry matter intake (DMI) with DDGS substitution, there were no advantages ($P \geq 0.33$) on gain efficiency, dietary energetic or observed-to-expected DMI. DDGS substitution did not affect dressing percentage and backfat thickness, but increased (linear, $P \leq 0.03$) hot carcass weight (HCW) and kidney, pelvic and heart fat (KPH) and decreased (linear, *P* = 0.05) *longissimus* muscle area (LM). There were no effects of substitution with DDGS on wholesale cuts or visceral mass. The estimated net energy of maintenance (MJ/kg) of DDGS was 9.79, 9.62 and 9.50 to DDGS substitution of 15, 30 and 45%, respectively. DDGS is suitable substitute for corn and for a portion of the corn and SBM in a finishing diet, however at high inclusion level tended to decrease LM area and increase KPH. The comparative DE value of DDGS may be considered similar to the DE value of the DR corn it replaced up to 30% in the finishing diets fed to lambs.

INTRODUCCIÓN

Durante el proceso de producción de los granos secos de destilería con solubles (DDGS), la fracción proteína, minerales, grasa y fibra se concentran tres veces en los co-productos comparándolos con el valor maíz. Por lo tanto, DDGS contienen aproximadamente 30% de PC (73% de proteína no degradable en rumen, UIP), 40% de FDN y 11% de grasa (NRC, 2007), y comúnmente su valor en el mercado es menor al del maíz (USDA, 2012).

La creciente oferta de DDGS probablemente disminuirá su costo como ingrediente para la alimentación, haciéndolo favorable para el uso como proteína y fuente energética en la producción ganadera. El alto potencial del valor nutricional de los DDGS puede ser utilizado para remplazar a los granos (Klopfenstein et al., 2008) o a los granos más una fuente proteica (Depenbusch , 2008) en dietas de finalización para ganado de engorda. Sin embargo, aparentemente, el valor nutricional del DDGS varía dependiendo del nivel de inclusión (Uwituze et al., 2010) o de la proporción de los ingrediente que está remplazando. (Dicostanzo y Wright, 2012). Históricamente los DDGS han sido utilizados en la alimentación de ganado de engorda y lechero, así como en cerdos y aves (Rosentrater, 2012). Aun y cuando los DDGS son un ingrediente apropiado para la alimentación de ovinos, el valor nutricional de este co-producto en dietas de finalización de esta especie no ha sido bien definido.

Hüls et al. (2006), reportaron que el valor nutricional de los DDGS era similar a una mezcla compuesta por un 56% de maíz y 44% de pasta de soya, cuando el 17,3% de maíz y 100% de pasta de soya fueron reemplazados por el 22,9% de DDGS en la dieta de finalización que contenía 72,2 % y el 10,2% de maíz y pasta de soya, respectivamente. Sin embargo, se sabe que los niveles de inclusión superiores a 25% puede afectar el valor nutricional de los DDGS (Vander Pol et al., 2005). Félix et al. (2012), informaron un efecto cuadrático en la ganancia diaria de peso en ovinos de engorda cuando la harina de maíz y de soya se sustituye por DDGS, siendo máxima en 20% del nivel de inclusión.

Estos investigadores argumentan que la composición química de los DDGS (alto contenido de FDN y grasas) son los responsables de la disminución en el valor alimenticio a altos niveles de inclusión. Leupp et al. (2009), han reportado que sustituir maíz rolado en seco hasta en un 60% de DDGS en dietas con 70% de concentrado, no encontraron efecto negativo en la digestión de MO del tracto total; aun y cuando la digestión de MO disminuyó y la eficiencia de producción microbiana aumentó con niveles mayores de inclusión de DDGS. En comparación con los novillos, los ovinos tienen una mayor capacidad para utilizar eficazmente el maíz rolado en seco (Theurer, 1986), por lo que los efectos asociativos, como resultado de la sustitución del maíz con DDGS pueden tener un impacto diferente en la digestión de nutrientes en ovinos de engorda. Sin embargo, hay muy poca información disponible sobre los efectos de la sustitución de los DDGS de maíz en el sitio y la extensión de la digestión de los nutrientes y la energía digestible en los ovinos alimentados con una dieta alta en energía.

Contrario al estudio de Félix y et al., (2012), Schauer et al. (2008), informaron que los ovinos se podrían alimentar hasta un 60% de DDGS (en base seca), en sustitución de 55% de cebada y 5% de harina de soya, sin afectar la calidad de la canal, lo que indica que el valor nutricional de los DDGS fue similar a la proporción de harina de cebada y soya sustituido en estas dietas. Debido a que en la mayoría de los tratamientos la pasta de soya fue reemplazada totalmente en los tratamientos de DDGS, la diferencia relativa en la concentración de proteínas entre las dietas testigo frente a las dietas suplementadas con alto nivel de DDGS fue hasta un 30%.

De la misma forma, las dietas generalmente no eran isoenergéticas cuando los DDGS reemplazaron parcialmente al maíz y totalmente a la pasta de soya en las dietas. Ambas situaciones hacen que sea difícil de determinar con precisión el valor nutricional de los DDGS incluidos en altos niveles en estos experimentos.

OBJETIVO

El propósito de estos experimentos fue evaluar el valor nutricional de los DDGS incluidos en niveles altos como sustitución parcial del maíz o del maíz y pasta de soya en dietas de finalización para ovinos de pelo.

HIPÓTESIS

Los DDGS pueden sustituir parcialmente al maíz o al maíz y pasta de soya en las dietas de finalización para ovinos de pelo, sin afectar a la función digestiva, comportamiento productivo, características de la canal y desarrollo de la masa órgano visceral.

REVISIÓN DE LITERATURA

Proceso de producción del etanol

Todas las actividades referentes a la obtención de etanol se describen a continuación paso a paso pero estas se concentran en cinco aspectos fundamentales, los cuales son la clave para la obtención de los granos secos de destilería con solubles (DDGS), los cuales se describen en la Figura 1.

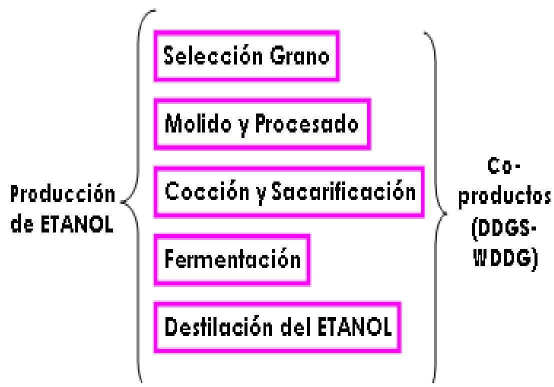

Figura 1. Proceso de producción de etanol.

Reducción del tamaño de partículas de los granos: El paso inicial en las plantas de molienda en seco para producción de etanol, es reducir el tamaño de partícula del maíz con la molienda de molinos de martillo. La fineza del maíz molido está determinada principalmente por el volumen del rotor, la velocidad de la punta del martillo, el número de martillos y el tamaño de la abertura de la malla (Dupin et al., 1997). Las mallas que se usan en el martillo normalmente están en un intervalo de 1/8 a 3/16 de pulgada de diámetro. El tamaño de partícula del grano puede afectar el rendimiento de etanol, y por lo tanto, los productores tienden a usar maíz molido muy fino para maximizar el rendimiento del etanol. Es decir se puede producir un extra de 0.85 litros (0.20 galones) de etanol si el maíz se muele para que pase por una malla de 3/16, en comparación con una de 5/16 de pulgada (Kelsall y Lyons, 1999).

Cocción y sacarificación: El agua y el destilado reciclado se añaden al maíz molido, los cuales actúan como acondicionadores para empezar la extracción de la proteína soluble, los azúcares y los lípidos ligados no almidonosos (Chen et al., 1999). La mezcla de lodos se cocina para hidrolizar el almidón y convertirlo a glucosa junto con las enzimas amilolíticas, para que las levaduras (*Saccharomyces cerevisiae*) conviertan la glucosa a etanol. Las temperaturas que típicamente se usan durante el proceso de cocción son de 40° a 60°C en el tanque de premezcla, 90° a 165°C para la cocción y 60°C para la licuación (Kelsall y Lyons, 1999).

La gelatinización del almidón comienza entre los 50° y 70°C. Un paso crítico en la conversión del almidón a la glucosa involucra la terminación de la gelatinización del almidón (Lin y Tanaka, 2006). Durante la gelatinización, se extrae casi toda la amilasa en los gránulos de almidón (Han y Hamaker, 2001), lo que incrementa la viscosidad debido a los gránulos hinchados y geles que consisten de amilasa solubilizada (Hermansson y Kidman, 1995).

Fermentación: La fermentación es el proceso en el que la levadura convierte a los azúcares en etanol. La levadura que más comúnmente se usa es la *Saccharomyces cerevisiae* por que puede producir etanol a una concentración de hasta 18% en el caldo de fermentación (Pretorius, 2000). Saccharomyces también está generalmente reconocida como segura (GRAS, por sus siglas en inglés) como aditivo para alimentos de consumo humano (Lin y Tanaka, 2006). En la fermentación modelo, alrededor de 95% de la azúcar se convierte a etanol y dióxido de carbono, 1% en materia celular de las levaduras y 4% en otros productos como el glicerol (Boulton et al., 1996). La levadura representa alrededor del 10% del costo económico de la producción de etanol (Wingren et al., 2003). La pre-fermentación se hace para lograr el número deseado de levaduras en la fermentación, proceso que implica la agitación durante 10 y 12 horas para lograr de 300 a 500 millones de levaduras/mililitro. La fermentación sucede a una temperatura de alrededor de 33° C, a un pH de alrededor de 4.0, y dura entre 48 y 72 horas (Thomas et al., 1996).

Además del etanol, se produce dióxido de carbono, el cual puede recolectarse o liberarse en el aire. El control del crecimiento normal de las levaduras es un factor importante en la producción eficiente del etanol. La actividad de las levaduras es altamente dependiente de la temperatura del sistema de fermentación (Ingledew, 1998).

Destilación de etanol: Después de la fermentación, durante el proceso, el etanol se recolecta con columnas de destilación. El etanol recolectado de los fermentadores se contamina con agua y se purifica con un sistema de tamices moleculares para eliminar el agua y producir etanol puro (Erickson et al., 2005).

Co-productos de la molienda seca: El agua y los sólidos que resultan después de la destilación del etanol se les conocen como destilado completo, que constituye principalmente de agua, fibra, proteína y grasa. Esta mezcla se centrifuga para separar los sólidos gruesos del líquido. Los sólidos gruesos también se les llaman pasta húmeda, la cual contiene alrededor del 35% de materia seca. La pasta húmeda se puede vender a los engordadores de ganado locales sin secarse, o se puede secar para producir los granos de destilería secos (DDG) (Erickson et al., 2005).

Características físicas y químicas de los granos secos de destilería con solubles de EUA

En lo que se refiere a las características físicas y químicas de los granos secos de destilería con solubles (DDGS) varían entre fuentes y pueden influir sobre su valor alimenticio y características de manejo. Entre estas características se incluye el color, olor, tamaño de partícula, densidad de masa y pH.

Color: El color de los DDGS puede variar desde ligeramente dorado a marrón oscuro. Las diferencias se deben al color inicial del grano, la cantidad de solubles añadidos a él para preparar DDGS y el tiempo y la temperatura de secado utilizados (Noll et al., 2006).

Olor: Los DDGS de alta calidad tienen un olor dulce, tipo fermentado. Los DDGS que tienen un olor a quemado o a humo están sobrecalentados (Noll et al., 2006).

Tamaño de partícula: El tamaño medio de partícula para los DDGS es aproximadamente 700 µm, pero el rango de este parámetro es extremadamente grande: varía de 73 a 1.217 µm entre diversos orígenes es decir dependiendo de la empresa que estos procedan. El tamaño de partícula es muy importante dado que afecta: la digestibilidad de los nutrientes, la eficiencia en el mezclado, cantidad de segregación, calidad del pellet, palatabilidad, densidad de masa e incidencia de ulceras gástricas (Pederson et al., 2005).

Densidad de masa: La densidad de masa es un factor importante a considerar cuando se determina el volumen de almacenamiento de los vehículos de transporte, barcos, contenedores, tambores y sacos. La densidad de masa afecta los costos de transporte y de almacenamiento. También afecta la cantidad de segregación del ingrediente que pueda haber durante el manejo de alimentos completos. Las partículas de densidad de masa mayores se van al fondo de una carga durante el transporte mientras que las partículas de densidad menores suben a la parte superior de la carga (Urriola et al., 2007).

pH: El pH medio es de 4.1; pero puede estar entre 3.6 y 5.0. Estos rangos se dan debido al efecto de variabilidad entre procesos de producción entre empresas o plantas productoras de etanol (Pederson et al., 2005).

Contenido de nutrientes de los granos secos de destilería con solubles

Los nutriólogos precisan de consistencia y predictibilidad en los ingredientes para alimentos balanceados que compran y utilizan. El contenido de nutrientes de los DDGS puede variar entre las fuentes (Cuadro 1), los cuales se ha mostrado que varían con el tiempo entre plantas.

Cuadro 1. Contenido nutricional de los granos secos de destilería con solubles (DDGS)

Nutrientes (%)	Maíz grano[1]	Rango DDGS	DDGS maíz [2]	NRC [3]	DDGS maíz [4]	DDGS maíz [5]	DDGS maíz [6]
Materia seca	90.0	87.3 - 2.4	92.0	90.2	88.9	88 - 90	89.1
Proteína cruda	9.8	28.7 - 2.9	30.9	29.7	30.2	25 - 32	30.1
Grasa cruda	4.3	8.8 - 12.4	10.7	10.0	10.9	8 - 10	10.7
FDN	3.3	-	-	38.8	42.1	39 - 45	41.5
FDA	4.1	-	-	19.7	16.2	-	16.1
Fibra cruda	2.4	5.4 - 10.4	8.5	-	-	-	-
Cenizas	4.1	3.0 - 9.8	6.0	5.2	5.8	-	5.2
Fósforo	0.3	0.42 - 0.99	0.8	0.8	0.9	0.78 - .08	0.8
Azufre	-	-	-	0.4	0.5	-	0.4

1, 3 NRC (2000 y2001)
2FEEDSTUFFS (2009)
4 Spiehs (2002)
5 Tjardes y Wrignt (2002)
6 Schingoethe (2004)

Variabilidad en el contenido de nutrientes de los DDGS

La composición nutricional de los DDGS varía de acuerdo con la fuente y calidad del grano utilizado durante la producción de etanol, además de las variaciones que pueden existir durante el proceso de obtención del biocombustible dentro de una misma planta o en plantas diferentes (Whitney, 2004). Los tres factores más importantes que afectan la variabilidad en el contenido de nutrientes son:

Contenido de nutrientes del grano*:* Se debe a la variación normal entre las variedades de granos y a las ubicaciones geográficas en donde se cultivan.

Relación de mezcla de solubles añadidos: Los DDGS se producen al mezclar solubles condensados con granos húmedos de destilería (CDS + WDG). La definición oficial de los DDGS publicada por la Asociación de Oficiales Americanos de Control de Alimentos (AAFCO) requiere que se mezcle al menos el 75% de los sólidos en el destilado completo con la pasta húmeda. Las plantas de etanol pueden variar la cantidad de solubles en la mezcla por arriba del 75% mínimo, sin embargo la variación de planta a planta en la relación de mezcla de los dos componentes de los DDGS va a afectar la composición de nutrientes (Ergul et al., 2003).

Temperatura de secado: Es probable que mucha de la diferencia en la composición nutricional de los DDGS y su digestibilidad se deba al tiempo y temperatura de secado que se usa para producirlos. Las temperaturas de la secadora pueden estar entre 126.5° - 620.5°C (260° - 1150º F), dependiendo de la planta (Stein et al., 2005).

Uso de los co-productos de destilería de EUA en las dietas para ganado bovino u ovino de engorda

Durante varias décadas se han publicado muchos trabajos y resúmenes de investigación los cuales han sido dirigidos al estudio de las características nutrimentales de los co-productos de destilería y su utilización en la alimentación de bovinos, dichos trabajos se han enfocado más en lo que se refiere a engorda de bovinos en finalización.

Los DDGS hoy en día representan una fuente de alimentación muy importante para los rumiantes debido a su alto contenido nutricional, su disponibilidad en el mercado y un precio competitivo en comparación con los granos tradicionales, basado en esto durante los últimos años se han realizado investigaciones para confirmar la eficiencia nutricional de los DDGS y su uso en dietas para bovinos y ovinos combinándose además con otros granos (Schingoethe et al., 2004).

El uso de los DDGS toma dos funciones según el nivel de inclusión en la dieta. Leupp et al. (2009), reportaron que en niveles de 6 a 15% base MS, su objetivo es servir como fuente de proteína, por lo cual, cuando son incluidas en niveles superiores los DDGS se convierten en una fuente de energía en sustitución del maíz (Klopfenstein et al., 2008).

Bovinos en finalización: Los DDGS son muy palatables y fácilmente consumibles por el ganado de engorda. Además, la alimentación de esta materia prima no cambia la calidad o rendimiento de los canales de las reses y no tiene efectos sobre las características sensoriales de su carne (Erickson et al., 2005). Usualmente los DDGS son utilizados como fuente de energía en dietas de finalización para bovinos (Erickson et al., 2006; May et al., 2009). Al comparar los DDGS con otros granos encontraron que el nivel de energía fue 120 a 150% superior en comparación con el maíz rolado y de 100 a 110% mayor que el gluten de maíz, dependiendo de la calidad de este último (Erickson et al., 2006).

La sustitución del maíz con granos húmedos de destilería ha resultado consistentemente en un mejoramiento del 15 al 25% de la conversión alimenticia, cuando se reemplaza del 30 al 40% del maíz con WDGS en la dieta. Este mejoramiento a la conversión alimenticia se debe principalmente a que los WDGS tienen de 120 a 150% del valor de la energía del maíz (Cuadro 2). El secado parece reducir el valor energético a 102 y 127% del valor energético del maíz rolado en seco en las dietas altas en forrajes. Parece que los altos valores energéticos de los WDGS y DDGS son el resultado del control de la acidosis (Larson et al., 1993; Trenkle, 1997; Fanning et al., 1999).

Vander Pol et al. (2005), mostraron que cuando se alimenta el ganado en finalización con dietas que contienen 10 al 20% de DDGS de la materia seca de la dieta, no hubo beneficio de suplementar las dietas con urea, lo que indica que hubo un reciclaje de nitrógeno.

Considerando las respuestas observadas en bovinos alimentados con dietas de finalización en corral, cuando se utilizan los DDGS como fuente de energía, Schingoethe et al. (2004), recomiendan niveles de inclusión del 10 al 40% base MS. Estos resultados son comparables con investigaciones realizadas por Gunn et al. (2009), Klopfenstein et al. (2008), y May et al. (2009), en las que demuestran que la inclusión de hasta 35% de DDGS no es perjudicial para el rendimiento de los animales, sin embargo, observaron que la eficiencia alimenticia se maximiza entre el 20% y 25% de inclusión.

Cuadro 2. Efecto de los co-productos húmedos o secos sobre el comportamiento del ganado en finalización. [1]

		Co-productos de destilería y nivel				
			DDGS			
Variable	T	WDB	Bajo	Med	Alto	SEM
GDP [3,4]	1.46	1.69	1.66	1.68	1.72	0.12
CMS [5,6]	10.9	10.6	11.4	11.4	11.7	0.55
G:F [3,4,6]	0.13	0.15	0.14	0.15	0.14	0.004

[1] Adaptado de Ham et al. (1994).
[2] DDGS = Granos secos de destilería con solubles y WDB = Co-productos húmedos de destilería.
ADIN = Nitrógeno insoluble ácido detergente.
[3] Testigo vs. WDB (*P* < 0.05).
[4] Testigo vs el promedio de los DDGS compuestos (*P* < 0.05).
[5] Testigo vs el promedio de los DDGS compuestos (*P* < 0.10).
[6] WDB vs el promedio de los DDGS compuestos (*P* < 0.05).

Ovinos en finalización: En ovinos existe poca documentación científica disponible que evalué niveles máximos de inclusión de DDGS en las dietas. En un estudio realizado por Schauer et al. (2008) evaluaron el efecto de la alimentación con distintos niveles (0, 20, 40, y 60% base MS) de inclusión en dietas de finalización llegando a la conclusión de que los DDGS mantuvieron el rendimiento y no presentaron efectos negativos sobre las características de la canal. Schauer et al. (2006) incorporando DDGS en niveles de hasta 15%, Hüls et al. (2006) sustituyendo hasta 23% y Zelinsky (2006) incluyendo hasta 17% base MS en dietas para ovinos en finalización no observaron diferencias en el comportamiento. Sin embargo, Schauer et al. (2006) reportaron un incremento en el rendimiento a medida que se incrementaba los niveles de DDGS hasta un 22.5% en la dieta. En lo referente al peso final (PF) de los ovinos Felix et al. (2011) reportaron un incremento de 8% (55.9 vs. 60.2 Kg) en el PF al incluir 20% de DDGS (base MS) en comparación con la dieta testigo (0% DDGS), sin embargo al incrementar los niveles de DDGS no observaron diferencias al igual que Hüls et al. (2006) al incluir 23% de DDGS. Para la ganancia diaria de peso (GDP), Félix et al. (2011) reportaron un incremento de 13% al incluir 20% de DDGS en comparación con la dieta testigo. Sin embargo al incluir niveles de 40 y 60% de DDGS reportó una reducción (4 y 5%, respectivamente) en la GDP en dietas de finalización para ovinos. En contraste, Schauer et al. (2008), quienes no observaron ningún efecto al incluir hasta 60% DDGS en la dieta.

Diferentes estudios realizados con DDGS y WDGS

El primer estudio diseñado para incluir granos destilería como una fuente de energía fue llevada a cabo por Farlin (1981). Este investigador utilizó para la prueba granos de destilería húmedos sin solubles (WDG) en distintos niveles de sustitución de 25, 50, y el 75% del maíz en una dieta de finalización. Aun y cuando la principal fuente energía (almidón) fue removida del maíz, el co-producto (WDG) resultó con mayor concentración de energía por kilogramo de materia meca con respecto del maíz.

Por otra parte, Firkins et al. (1985) y Trenkle (1996, 1997) observaron resultados similares cuando sustituyeron maíz quebrado u hojuleado con vapor por distintos niveles de WDGS.

De la misma forma, Ham et al. (1994) compararon los valores alimenticios de DDGS y WDGS en las dietas de finalización para ganado de engorda. Se sustituyó maíz rolado en seco (DRC) por granos húmedos de destilería (WDGS) y granos secos de destilería con solubles (DDGS) en combinación con solubles condensados (CDS). Los DDGS se obtuvieron de 11 destiladoras comerciales; posteriormente se determinó la cantidad de ADIN (Nitrógeno insoluble en ácido detergente, por sus siglas en inglés) como marcador de daño por cocción. Los animales alimentados con 40% DDGS, 15% CDS o DRC aumentaron el CMS en comparación con los tratamientos que contenían WDG+CDS y DDGS+Agua (27% y 13%, respectivamente). Adicionalmente, el tratamiento que DDGS+Agua, obtuvo un 14% menos de concentración de AGV (mM) en comparación con los demás tratamientos, sugiriendo esto, que los DDGS y MRS con o sin CDS tienen un valor nutricional similar.

Diferentes estudios conducidos en Iowa y la Universidad de Nebraska concluyen que los DG (húmedos o secos; con o sin solubles), pueden ser incluidos desde un 10 a 15% de la dieta (base MS) como fuente suplementaria de proteína en las etapas de desarrollo y finalización. Cuando son añadidos a niveles mayores del 15% de la dieta, los DG también son una fuente energética en la dieta, reemplazando al maíz u otros cereales. Los DG pueden ser ofrecidos a niveles de hasta 20% de la dieta en base MS. Los WDGS pueden ser incluidos en las dietas de desarrollo y finalización a niveles de hasta 40% de la dieta en base a MS. Sin embargo, a estos niveles, las dietas contienen exceso de proteína y fosforo, lo que puede ocasionar complicaciones con respecto al manejo del estiércol para el productor. La mayoría de los datos de investigación indican que el nivel óptimo de los WDGS es 25% de la dieta en base a MS o menos.

Cuadro 3. Resumen de resultados encontrados por diferentes autores

Autor	Nivel óptimo de inclusión de DDG	Variables	
		CMS	GDP
Hicks et al., (2008)	**D-0**	10.32	1.78
Buckner et,al., (2007)	**D-20**	9.52	1.68
Benson et al., (2005)	**D-30**	10.56	1.71
Ham et al., (1994)	**D-40**	11.73	1.72

CMS: Consumo de materia seca kg /día.
GDP: Ganancia de peso diaria kg /día.

El metabolismo y la digestión de los granos de destilería

Trenkle (1997) estima que la concentración de proteína no-degradable en Rumen (PNDR, o proteína de sobrepaso) y grasa contenido en los WDGS hace aún más atractivo su uso como ingrediente proteico o energético; especialmente en dietas con forraje de mala calidad. Debido al bajo contenido de almidón en los WDGS, estas dietas tienen menos efectos negativos en la digestión de la fibra que las que tienen un alto nivel de almidón. En dietas con forrajes que contengan bajos niveles de fósforo, el contenido de este mineral en los WDGS podría ser de mucho beneficio.

Posteriormente, Vander Pol et al. (2007) llevaron a cabo un experimento con ganado de engorda en finalización para evaluar el efecto de los lípidos en DDGS. Se tuvieron cinco dietas: Una con WDGS; y las cuatro restantes fueron combinaciones de DRC, fibra de maíz y gluten de maíz, todo esto con o sin aceite de maíz. La dieta con WDGS obtuvo mayor digestibilidad de tracto total de la MO, FDN y grasa. La digestibilidad de la grasa en los WDGS fue mayor (81%) en comparación con los tratamientos adicionados con aceite de maíz

(71%), sugiriendo que ocurrió alguna protección de dicha grasa. Los animales que recibieron WDGS y dieta testigo (con o sin aceite de maíz) tuvieron mayores ($P<0.10$) proporciones de AGCL 16:0 (palmítico) llegando a duodeno en comparación con las otras dietas. En cuanto a las ácidos grasos de cadena larga, los animales que recibieron dietas suplementadas con aceite de maíz tuvieron mayores ($P<.10$) proporciones de AGCL 18:0 (esteárico) llegando a duodeno; mientras que los que recibieron dietas con WDGS tuvieron la menor ($P<0.10$) cantidad de 18:0 llegando a duodeno. Estos datos, indican que los ácidos grasos en WDGS no son hidrogenados en rumen al mismo grado que los ácidos grasos del aceite de maíz suplementado. Esto a su vez, coincide con otros estudios (Zinn et al., 2000; Plascencia et al., 2003) que sugieren que los ácidos grasos insaturados tienen mayor digestibilidad que los ácidos grasos saturados.

Lo anterior es de importancia ya que una de las características químicas de los DDGS es su alto contenido de grasa (9-12%). Y las grasas son importantes desde un punto de vista energético. Zinn (1989) señala que el nutriente con mayor densidad energética para los rumiantes son los lípidos.

Efecto *de los DDGS sobre la digestibilidad de nutrientes: MS, FDN, N*

Tal vez el desafío más grande de usar los granos secos de destilería con solubles (DDGS) como alimento para animales es conocer el contenido y digestibilidad de los nutrientes, basado en esto se han desarrollado diferentes investigaciones en la búsqueda de resultados que permitan comprender la respuesta fisiológica que implica la utilización de estos subproductos en las dietas para rumiantes.

Materia Seca: En ovinos en crecimiento Felix et al. (2011) al incluir 20% de DDGS observaron un incremento de 2% en la digestibilidad en comparación con el control. De igual manera Li et al. (2011) en vaquillas Angus reportaron un incremento de 2% al incluir el mismo nivel. En contraste, Gibb et al. (2008) habían informado que la digestibilidad de la MS fue 9.8% al incluir hasta 60% de DDGS. Sin embargo, Walter et al. (2011) no observaron diferencias en la digestibilidad.

***Fibras**:* En un estudio de Leupp et al. (2009) alimentando con grandes cantidades de DDGS (60% MS) en raciones con 70% de concentrado no observaron efectos sobre la digestibilidad de FDN, pero si una tendencia a disminuir la digestibilidad de la FDA. Walter et al. (2011) incluyeron DDGS en niveles de 20 y 40% en dietas de finalización para vaquillas y observaron un incremento en la digestibilidad de la FDA de 42 y 30%, respectivamente, de igual manera sucedió con la FDN con valores de 23 y 32% a medida que incremento el nivel de DDGS en la dieta.

Nitrógeno: La inclusión de DDGS en dietas y suplementos para ovinos ha mejorado la digestibilidad de N en comparación con las dietas testigo. Archibeque et al. (2007) al incluir 93.4% de DDGS en un suplemento para ovinos reportaron un aumento en la digestibilidad de 18%, estos resultados guardan relación con Felix et al. (2011), quienes al incluir hasta 60% de DDGS en dietas de crecimiento para ovinos observaron un incremento de 8% en la digestibilidad de N.

CONCLUSIONES

La disponibilidad de los granos de destilería como alimento para los rumiantes se incrementara a medida que la industria del etanol se expande. Actualmente se utilizan como una alternativa alimenticia por su alto valor nutricional en comparación con los granos tradicionales utilizados en la alimentación animal.

Los granos de destilería son altos en fibra, proteína y grasa y gracias a esto se ha podido utilizar como fuente de proteína cuando han sido incluidos en niveles inferiores al 15% base MS o bien como fuente de energía cuando se incluyen a niveles mayores del 20%.

Los efectos de los granos de destilería sobre el comportamiento productivo del animal no son influenciados por el tipo de grano fermentado. Con respecto a la forma física (húmedos vs secos) de los subproductos, los estudios indican que los húmedos tienen mejores respuestas productivas, sin embargo el principal problema de este tipo de co-producto es el almacenaje.

Pudiera existir un efecto entre el nivel de los DDGS en la dieta y el tipo de procesamiento de granos utilizados. Esto significa que el desempeño se puede influenciado por el método de procesamiento de los granos que son incluidos en las dietas basales.

Los efectos de los granos de destilería sobre el desempeño y metabolismo animal en bovinos de engorda están hasta cierto punto estudiados y definidos, sin embargo en ovinos en finalización no se cuenta con la suficiente información al respecto.

LITERATURA CITADA

Archibeque, S.L., H.C. Freetly, and C.L. Ferrell. 2008. Feeding distillers grains supplements to improve amino acid nutriture of lambs consuming moderate-quality forages. J. Anim. Sci.86:691-701.

Benson, C.S., C.L. Wright, K.E. Tjardes, R.E. Nicolai and B.D. Rops. 2005. Effects of feeding varying concentrations of dry distiller's grains with solubles to finishing steers on feedlot performance, nutrient management and odorant emissions. South Dakota Beef Rep. 13:59.

Boulton, B., V.L. Singleton, L.F. Bisson and R.E. Kunkee. 1996. Yeast and biochemistry of ethanol fermentation. In: B. Boulton, V.L. Singleton, L.F. Bisson, and R.E. Kunkee editors, Principles and Practices of Winemaking. Chapman and Hall. New York, NY, USA. p.139-172.

Buckner, C.D., T.L. Mader, G. E. Erickson, S.L. Colgan, K. K. Karges, and M. L. Gibson. 2007. Optimum levels of dry distillers grains with solubles for finishing beef steers. Nebraska Beef Cattle Report. MP90:36–38.

Chen, J.J., S. Lu, and C.Y. Li. 1999. Effect of milling on physicochemical characteristics of waxy rice in Taiwan. Cereal Chem. 76:796-799.

Depenbusch, B.E., E.R., Loe, M.J. Quinn, M.E. Corrigan, M.E., Gibson, M.L., Karges, and K.K., Drouillard. 2008. Corn distillers grains with solubles derived from a traditional or partial fractionation process: Growth performance and carcass characteristics of finishing feedlot heifers. J. Anim. Sci. 86: 2338-2346.

Dicostanzo, A., and C.L., Writhe. 2012. Feeding Ethanol Coproducts to Beef Cattle. In: K. Lui, and K.A. Rosentrater editors, Distiller grain, production properties and utilization. CRC Press, Boca Raton, FL. p. 391-397.

Dupin, I. V. S., B. M. McKinnon, C. Ryan, M. Boulay, A.J. Markides, P. J. Graham, P. Fang, Q., I. Boloni, E. Haque, and C.K. Spillman. 1997. Comparison of energy efficiency between roller mill and a hammer mill. Appl. Eng. Agric.13:631-635.

Ergul, T., C. Martinez Amezcus, C. M., Parsons, B. Walters, J. Brannon, and S. L. Noll. 2003. Amino acid digestibility in corn distillers dried grains with solubles. Poultry Sci. 82 (Suppl. 1): 70.

Erickson, G.E., T.J. Klopfenstein, D.C. Adams, and R.J. Rasby. 2005. General overview of feeding corn milling coproducts to beef cattle. In: Corn Processing Co-Products Manual. University of Nebraska. Lincoln, NE, USA.

Erickson, G.E., T.J. Klopfenstein, D.C. Adams, and R.J. Rasby. 2006. Utilization of Corn Co-Products in the Beef Industry. Nebraska Corn Board and the University of Nebraska. www.nebraskacorn.org. 17 pp.

Fanning, K., T. Milton, T. Klopfenstein, and M. Klemesrud. 1999. Corn and sorghum distillers grains for finishing cattle. Nebraska Beef Rep. MP 71 A:32.

Farlin, S. D. 1981. Wet distillers grains for finishing cattle. Anim. Nutr. Health 36:35–36.

Feedstuffs. 2009. Ingredient Analysis Table. Disponible en: http://www.feedstuffs.com. Accesado en: Septiembre, 15, 2010.

Felix, T. L., H. N. Zerby, S. J. Moeller, and S. C. Loerch. 2012. Effects of increasing dried distillers grains with solubles on performance, carcass characteristics, and digestibility of feedlot lambs. J. Anim. Sci. 90: 1356-1363

Firkins, J. L., L. L. Berger, and G. C. Fahey Jr. 1985. Evaluation of wet and dry distillers grains and wet and dry corn gluten feeds for ruminants. J. Anim. Sci. 60:847–860.

Gibb, D. J., X. Hao, and T. A. McAllister. 2008. Effect of dried distillers grains from wheat on diet digestibility and performance of feedlot cattle. Can. J. Anim. Sci. 88:659–665.

Gunn, P. J., A. D. Weaver, R. P. Lemenager, D. E. Gerrard, M.C. Claeys, and S. L. Lake. 2009. Effects of dietary fat and crude protein on feedlot performance, carcass characteristics and meat quality in finishing steers fed differing levels of dried distiller's grains with solubles. J. Anim. Sci. 87:2882–2890

Ham, G. A., R. A. Stock, T. J. Klopfenstein, E. M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers grains with solubles as a source of protein and energy for ruminant. J. Anim. Sci. 72:3246–3257.

Han, X.Z, and B.R. Hamaker. 2001. Amylopectin fine structure and rice starch paste breakdown. J. Cereal Sci. 34:279-284.

Hermansson, A.M., and S. Kidman. 1995. Starch – A phase-separated biopolymer system. In: S.E. Harding, S.E. Hill, and J.R. Mitchell, Editors, Biopolymer Mixtures, Nottingham University Press, UK. p.225-245.

http://www.grains.org/galleries/DDGS%20User%20Handbook/DDGS%20Handbook ESP.pdf Asociación Nacional de Granos de los Estados Unidos de América. Manual de producción de etanol y uso de sus coproductos.

Hicks, R.B.. 2008. Use of Distiller's Grains (Wet & Dry) in Flaked Corn Diets Pages 57-67 in Oklahoma Panhandle Research and Extension Center Research Highlights.

Ingledew, W.M. 1998. Alcohol production by *Saccharomyces cerevisiae*: A yeast primer. In: K.A. Jacques, T.P. Lyons, and D.R. Kelsall, editors, The alcohol textbook (3rd Ed.). Nottingham University Press. Nottingham, UK.

Kelsall, D.R., and T.P. Lyons. 1999. Grain dry milling and cooking for alcohol production: designing for 23% ethanol and maximum yield. In: K.A. Jacques, T.P. Lyons, and D.R. Kelsall editors, The alcohol textbook (3rd Ed.). Nottingham University Press. Nottingham, UK.

Klopfenstein, T. J., G. E. Erickson, and V. R. Bremer. 2008. Use of distillers by-products in the beef cattle feeding industry. J. Anim. Sci. 86:1223–1231.

Klopfenstein, T., J. Waller, N. Merchen, and L. Petersen. 1978. Distillers grains as a naturally protected protein for ruminants. Distillers Feed Conference Proceedings 33:38–46.

Larson, E.M., R.A. Stock, T.J. Klopfenstein, M.H. Sindt, and R.P. Huffman. 1993. Feeding value of wet distillers co-products from finishing ruminants. J. Anim. Sci. 71:2228-2236.

Leupp, J.L., G.P. Lardy, K.K. Karges, M. L. Gibson, and J.S. Caton. 2009. Effects of increasing level of corn distillers dried grains with solubles on intake, digestion, and ruminal fermentation in steers fed seventy percent concentrate diets. J. Anim. Sci.87:2906-2912.

Lin,Y., and S. Tanaka. 2006. Ethanol fermentation from biomass resources: current state and prospects. Appl. Microbiol. Biotechnol. 69: 627-642.

May, M. L., M. J. Quinn, C. D. Reinhardt, L. Murray, M. L. Gibson, K. K. Karges, and J. S. Drouillard. 2009. Effects of dry-rolled or steam-flaked corn finishing diets with or without twenty-five percent dried distillers grains on ruminal fermentation and apparent total tract digestion. J Anim Sci. 87:3630-3638.

Noll, S., C. Parsons, and B. Walters. 2006. What's new since September 2005 in feeding distillers co-products to poultry. 67th Nutr. Conf. Procc. University of

Minnesota Res. Update Session: Livestock Production in the New Millenium, St. Paul, MN. 149-154.

NRC. 2000. Nutrient Requirements of Beef Cattle (7th Ed.). National Academy Press, Washington, DC.

Pederson, C., A. Pahm, and H.H. Stein. 2005. Effectiveness of in vitro procedures to estimate CP and amino acid digestibility coefficients in dried distillers grain with solubles by growing pigs. J. Anim. Sci. (Suppl. 2) 83:39.

Plascencia, A., G. D. Mendoza, C. Vásquez, and R. A. Zinn. 2003. Relationship between body weight and level of fat supplementation on fatty acid digestion in feedlot cattle. J. Anim. Sci. 81:2653–2659.

Pretorius, I.S. 2000. Tailoring wine yeast for the new millennium: Novel approaches to the ancient art of winemaking. Yeast 16:675-729.

Rosentrater, K.A. 2012. Feeding DDGS in other animals. In: K. Lui, K. A., Rosentrater editors, Distiller grain, production properties and utilization. CRC Press, Boca Raton, FL. p. 391-397.

Schauer, C.S., M.M. Stamm, T.D. Maddock, and P.B. Berg. 2008. Feeding dried distillers grains with solubles as 60 percent of lamb finishing rations results in acceptable performance and carcass quality. North Dakota State University. Sheep & Goat Res. J. Vol. 23.

Schauer, C.S., P.B. Berg, M. Stamm, D.M. Stecher, D. Pearson, and D. Drolc. 2006. Influence of dried distillers grains on feedlot performance and carcass characteristics of finishing lambs. Western Dakota Sheep & Beef Day. 47:34-37.

Schingoethe, D.J. 2004. Corn Co-products for Cattle. Proceedings from 40th Eastern Nutrition Conference, May 11-12, Ottawa, ON, Canada. pp 30-47.

Spiehs, M.J., M.H. Whitney, and G.C. Shurson. 2002. Nutrient database for distiller’s dried grains with soluble produced from new ethanol plants in Minnesota and South Dakota. J. Anim. Sci. 80:2639.

Stein, H., A. Pahm, and C. Pedersen. 2005. Methods to determine amino acid digestibility in corn byproducts. In: Proceedings of the 66th Minnesota Nutrition Conference. St. Paul. MN. USA. 35-49.

Thomas, K.C., S.H. Hynes, and W.M. Ingledew. 1996. Practical and theoretical considerations in the production of high concentrations of alcohol by fermentation. Proc. Biochem. 31:321-331.

Tjardes, J., and C. Wright. 2002. Feeding corn distiller's co-products to beef cattle. SDSU Extension Extra. Ex 2036, August 2002. Dept. of Animal and Range Sciences. pp. 1-5.

Trenkle, A. 1997. Substituting wet distillers grains or condensed solubles for corn grain in finishing diets for yearling heifers. Beef Research report – Iowa State University ASRI 451.

Trenkle, A.H. 1996. Evaluation of wet distillers grains for finishing cattle. Beef Res. Rep., Iowa State Univ., Ames. AS632:75–80.

Urriola, P.E., D. Hoehler, C. Pederson, H.H. Stein, L.J. Johnston, and G.C. Shurson. 2007. Prediction of in vivo amino acid digestibility in dried distillers grains with solubles (DDGS) from crude protein, optical density and fluorescence. J. Anim. Sci. 85(Suppl. 2):31.

Uwituze, S., G.L., Parsons, M.K., Shelor, B.E., Depenbusch, K.K., Karges, M.L., Gibson, C.D., Reinhardt, J.J., Higgins, y and J.S. Drouillard. 2010. Evaluation of dried distillers grains and roughage source in steam-flaked corn. J. Anim. Sci. 88, 258-274.

Vander Pol, K. J., M.K. Luebbe, G.I. Crawford, G. E. Erickson and T.J. Klopfenstein. 2007. Digestibility, rumen metabolism and site of digestion for finishing diets containing wet distillersgrains or corn oil. Nebraska Beef Cattle Report. MP90:39–42.

Walter, L.J., T.A. McAllister, W.Z. Yang, K.A. Beauchemin, M.He, and J.J. McKinnon. 2011. Comparison of wheat or corn dried distillers grains with soluble on rumen fermentation and nutrient digestibility by feedlot heifers.J. Anim. Sci. 90:1291-1300.

Whitney, M.H., and Shurson, G.C. 2004. Growth performance of nursery pigs fed diets containing increasing levels of corn distiller’s dried grains with solubles originating from a modern Midwestern ethanol plant. J. Anim. Sci. 82:122-128.

Wingren, A., M., Galbe, and G. Zacchiu. 2003. Techno-Economic Evaluation of Producing Ethanol from Softwood: Comparison of SSF and SHF and Identification of Bottlenecks. Biotechnol. Prog. 19:1109-1117.

Zelinsky, R., J. Daniel, and J. Held (2006). The Effect of Corn or Soybean Hull Diets Supplemented with Dried Distillers Grain with Solubles (DDGS) on Finishing Lamb Performance and Carcass Merit. South Dakota State University Cooperative Extension Service, Sheep Research Report.

Zinn, R. A. 1989. Influence of level and source of dietary fat on its comparative feeding value in finishing diets for steers: Feedlot cattle growth and performance. J. Anim. Sci. 67:1029–1037.

Zinn, R. A., S. K. Gulai, A. Plascencia and J. Salinas. 2000. Influence of ruminal biohydrogenation on the feeding value of fat in finishing diets for feedlot cattle. J. Anim. Sci. 78:1738–1746.

EXPERIMENTO I

Heading title: DDGS on digestive function in drylot lambs

Effects of replacing dry-rolled corn with increasing levels of corn dried distillers grains with solubles (DDGS) on characteristics of digestion in hair lambs fed high-concentrate diets

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Artículo aceptado en el Animal Science Journal ISSN 1344-3941

ABSTRACT

Four cannulated lambs were used to evaluate the effect of levels of dry distillers grain with solubles (DDGS) supplementation (0, 10, 20 and 30%, dry matter basis) as a replacement for dry-rolled (DR) corn in finishing diets on digestive function. Treatments did not influence ruminal pH, flow to the small intestine of microbial nitrogen (MN) and MN efficiency. Postruminal digestion of organic matter (OM), starch, lipids and nitrogen (N) were not affected by treatments. However, the replacing corn with DDGS increased (linear) duodenal flow of lipids, neutral detergent fiber (NDF) and N. Substitution of DR corn with DDGS increased ruminal NDF digestion (quadratic effect), but decreased ruminal OM digestion (linear effect). Total tract digestion of N increased (linear) as the DDGS level increase, but DDGS substitution tended to decrease total tract digestion of OM (P = 0.06) and digestion of gross energy (P = 0.08). However, it did not affect the dietary digestible energy (Mcal/kg), reflecting the greater gross energy content of DDGS versus DR corn in the replacements. The comparative DE value of DDGS may be considered similar to the DE value of the DR corn it replaced up to 30% in the finishing diets fed to lambs.

Key words: *corn, DDGS, digestion, finishing diets, lambs.*

INTRODUCTION

During the production process of corn dry distillers grain with solubles (DDGS), protein, minerals, fat and fiber are concentrated three-fold as co-products when compared with corn. Therefore, corn DDGS contains approximately 30% crude protein (CP, 73% ruminal undegradable intake protein, UIP) and 11% fat (NRC 2000), and often costs less than corn (USDA 2010). Historically DDGS has primarily been fed to beef cattle, dairy animals include dairy sheep, swine and poultry (Rosentrater 2012). Even though DDGS should be appropriate as a feed ingredient for sheep, there are limited reports in terms of the effects on digestive function and the energy value of DDGS for this species. The high potential of the nutritional value of DDGS can be useful for replacing dry-rolled (DR) or steam-flaked corn in growing-finishing diets of beef cattle (Klopfenstein 2008). However, it appeared that the feed value of distillers grains may vary by level of inclusion (Uwituze *et al*. 2010) and by the type of processing (dry rolled or steam-flaked) of the corn grain that is replaced (May *et al*. 2009; Luebbe *et al*. 2012). The optimal responses (daily weight gain and feed efficiency) in feedlot cattle when DDGS has replaced corn grain in finishing diets have been observed with moderate levels (i.e. 20%) of DDGS inclusion as a replacement of steam-flaked grain (May *et al*. 2009; Uwituze *et al*. 2010; Luebbe *et al*. 2012). Leupp et al. (2009) have reported that replacing DR corn with up to 60% DDGS in 70% concentrate diets resulted in no adverse effects on total tract OM digestion in steers, although ruminal OM digestion decreased and microbial production efficiency increased with increasing DDGS. Compared to steers, lambs has a greater ability to effectively utilize DR corn (Theurer 1986); thus, the associative effects as a result of the replacement of DR corn with DDGS can have a different impact on nutrient digestion in fattening lambs. However, very little information is available on the effects of DDGS replacing DR corn on site and the extent of digestion of nutrients and digestible energy in lambs fed a high-energy diet.

Consequently, the objective of this study was to determine the effects of DDGS supplementation levels replacing DR corn on digestive function in lambs fed a high-energy DR corn-based diet.

MATERIAL AND METHODS

Animals, diets and sampling

The trial was conducted at the Ruminant Metabolism Experimental Unit of the Instituto de Investigaciones en Ciencias Veterinarias of the Universidad Autónoma de Baja

California, located 10 km south of Mexicali City in northwestern México (32° 40' 7”N and 115° 28' 6”W). The area is about 10 m above sea level, and has Sonoran desert conditions (BWh classification according Köppen). All procedures involving live animals were conducted within the guidelines of the approved local official techniques of animal care.

Four male lambs (Katahdin; average live weight 25.9 ± 2.9kg) with “T” type cannulas in the rumen and proximal duodenum (4 cm from the phyloric sphincter) were used in a 4 × 4 Latin square experiment to evaluate the influence of supplemental DDGS levels in the substitution of DR corn on characteristics of digestive function. Four dietary treatments were compared: 1) Control (0% DDGS); 2) 10% DDGS; 3) 20% DDGS; and 4) 30% DDGS. Diets were formulated to be isocaloric but not isonitrogenous, because the protein level increases as the level of DDGS replacing corn in the diet increased (Table 1). Chromic oxide (used as a source of chromium to estimate nutrient flow and coefficient of digestion) was added to the diets. Chromic oxide (4 g/kg of diet air dry basis) was premixed with minor ingredients (urea and mineral supplement composed of limestone and trace mineral salts) before incorporation into complete mixed diets. White corn was used as source of grain in the form of a commercial blend obtained from Mexico. Corn was prepared by passing whole corn through rollers (46 × 61cm rolls, 5.5corrugations/cm; Memco, Mills Rolls, Mill Engineering & Machinery Co., Oklahoma, CA) and machinery that had been adjusted so that the kernels were broken into a bulk density of 0.70 kg/L. The forage source of diet (sudangrass hay) was ground in a hammer mill (Bear Cat #1A-S**,** Westerns Land and Roller Co., Hastings, NE) with a 3.81cm screen, before incorporation into complete mixed diets. The source of DDGS used was a corn DDGS named for its appearance (color) as “Golden” and was obtained in an ethanol production facility with a 0.8% maximal content of sulfur (Pinal Energy LLC, Maricopa, AZ). All lambs received *ad libitum* access to the corn-basal diet (0% DDGS) for 14 days before the initiation of the trial. To avoid refusals, feed intake (as feed basis) was restricted to

750 g/d (90% of *ad libitum* intake of lambs during the 14-d preliminary period). As result to their intake level, the crude protein intake and energy intake (Table 2) meet the requirements for a lamb of 26 kg BW has a weight gain of 100 g/d (NRC 2007). Lambs were maintained in individual metabolism crates (1.2 × 1.6 × 0.7m) in an indoor facility with access to water at all times. Diets were fed in two equal proportions at 0800 and 2000 hours daily. Experimental periods consisted of a 17-d diet adjustment period followed by a 4-d collection period. During the collection period, duodenal and fecal samples were taken from all lambs twice daily as follows: d 1, 0750 and 1350 h; d 2, 0900 and 1500 h; d 3, 1050 and 1650 h; and d 4, 1200 and 1800 h. Individual samples consisted of 150 mL duodenal chyme and total fecal material. Samples from each lamb and within each collection period were composited for analysis. During the final day of each collection period, a ruminal sample was obtained from each lamb 4 h after feeding via the ruminal cannula. Ruminal fluid was taken from the ruminal ventral sac using tygon tubing (i.d. 0.95 cm; USP Lima, Ohio) adapted to a 100 mL syringe (Medical plastic appliance, Jiangzu, China), and the pH was determined (Orion 261S, Fisher Scientific, Pittsburgh, PA) on fresh samples. Upon completion of the trial, approximately 4 h after feeding a total of 2 L of ruminal fluid was obtained from all lambs. Total ruminal fluid was composited and poured in a closed jar protected from light and was mixed (1:1) with a saline solution warmed up to 40-45°C and immediately taken to the laboratory for the isolation of ruminal bacteria via differential centrifugation (Bergen et al. 1968). The microbial isolate served as the purine:N reference for the estimation of microbial nitrogen (MN) contribution to chyme entering the small intestine (Zinn & Owens 1986).

Sample analysis and calculations

The bulk density of DR corn and DDGS was measured using a standard bushel tester (OHAUS grain scale Model 8324915, Parssipani, NJ, USA) following the method prescribed by the USDA (1999).

Ingredients (DDGS and DR corn), feed, and duodenal and fecal samples were subjected to the following analysis: Dry matter (DM, oven drying at 105°C until no further weight loss; method 930.15, AOAC 2000); ash (method 942.05, AOAC 2000), Kjeldahl nitrogen (method 984.13, AOAC 2000); neutral detergent fiber (NDF, Van Soest *et al*. 1991, corrected for NDF-ash) incorporating heat stable α-amylase (Ankom Technology, Macedon, NY) at 1mL per 100mL of NDF solution (Midland Scientific, Omaha, NE); lipids (acid chloroform-methanol extraction; Zinn 1994); chromic oxide (Hill & Anderson, 1958); and starch (Zinn 1990). In addition, gross energy (**GE**, using the adiabatic bomb model 1271; Parr Instrument Co., Moline, IL. USA) was determined for feed and fecal samples. Ammonia N (method 941.04, AOAC 2000) and purines (Zinn & Owens 1986) were determined in duodenal samples. OM of feed, duodenal, and fecal samples was determined by difference between DM and ash content. Microbial OM and N leaving the abomasum were calculated using purines as a microbial marker (Zinn & Owens 1986). Organic matter that had fermented in the rumen was considered equal to OM intake minus the difference between the amount of total OM reaching the duodenum and the microbial OM reaching the duodenum. Feed N escape into the small intestine was considered equal to total N leaving the abomasum minus ammonia-N and MN and, thus, included any endogenous contributions.

Statistical design and analysis

The experimental design for this study was a 4 × 4 Latin square. Statistical data were analyzed using the MIXED procedure of SAS (2004). Fixed effects consisted of treatments, and random effects consisted of lambs and period. The statistical model for the trial was as follows:

$$Y_{ijk} = \mu + L_i + P_j + T_k + E_{ijk},$$

where: Y_{ijk} is the response variable, μ is the common experimental effect, L_i is the lamb effect, P_j is the period effect, T_k is the treatment effect and E_{ijk} is the residual error.

Treatment effects were tested for the following orthogonal components: 1) linear effect of DDGS level; 2) quadratic effect of DDGS level; and 3) cubic effect of DDGS level. Coefficients for polynomial contrasts (linear, quadratic and cubic effects of DDGS level) with equal spacing (0, 10, 20 and 30%) were determined according to SAS (2004). Contrasts were considered significant when the *P*-value was ≤ 0.05, and as a tendency approaching significance with a *P*-value of ≤ 0.10.

RESULTS AND DISCUSSIONS

During experimental phase there were no obvious health problems or feed refusals.

Physical and chemical characteristics of DDGS and replaced corn

The physicochemical composition of DDGS and corn used in the trial and their relative values according to the NRC (2007) are shown in Table 2. The bulk density of DDGS obtained here corresponds closely to the average bulk density (bulk density varied between 0.389 and 0.502 kg/L) reported previously by Rosentrater (2006). While that bulk density of DR white corn was 40% greater than that reported by Plascencia *et al*. (2011); thus, there was greater coarse-processing of the corn used in the current study. The nutrient composition of white corn used in the present experiment was consistent with previous reports (Sánchez *et al*. 2007; Plascencia *et al*. 2011). Compared to the values assigned to DDGS by the NRC (2007), the relative values of CP, NDF, lipids and ash were 0.90, 0.99, 0.85, and 0.93, respectively. According to the NRC (2007), the main constituent is the NDF, followed by the CP, although this proportion can be changed by the quantity of solubles added during the process (Kim *et al*. 2008). As a result, much of the variation in the composition of DDGS can be attributed to plant-to-plant differences in the proportions of distillers solubles added during processing (Spiehs *et al*. 2002; Kim *et al*. 2008). Due to the greater lipids content of DDGS than that of the DR corn, and compared to the control diet, increasing the DDGS level in the diet increased (linear component; $P < 0.01$, Table 3) the lipid intake by 7.0, 11.7 and 15.8 g/d to 10, 20 and 30% DDGS levels, respectively. These values represent a concentration of 8.8% of the total lipids in DDGS and correspond closely to the total lipids determined by analysis (Table 2) and those reported in DDGS previously (NRC 2000; Srinivasan *et al*. 2005; Leupp *et al*. 2009; Berger & Singh 2010). The average ash content was very similar compared to the results obtained by Spiehs *et al*. (2002) and Belyea *et al*. (2004) but was nearly 50% lower than the average obtained by Bhadra *et al*. (2007).

Characteristics of ruminal pH and site and extent of digestion

The treatment effects on ruminal pH and site and extent of digestion are shown in Table 3. The ruminal pH (sampling 4 hour *postpandrium*) averaged 6.20 ± 0.29, and was not affected ($P \geq 0.15$) by treatment, even though the starch intake decreased (Table 3; linear component, $P < 0.01$) with greater dietary DDGS levels. This could be due to the potential acidity of DDGS, which came from H_2SO_4, a standard treatment in the ethanol production industry (McAloon *et al*. 2000). In this sense, Felix and Loerch (2011) reported that feeding DDGS (with S content of 0.74%) at greater inclusions (60%) reduced ruminal pH in cattle. Likewise, previous studies reported no differences in ruminal pH when 20% (Peter *et al*. 2000) or 40% (Ham *et al*. 1994) DDGS was included in finishing diets to steers. In contrast, Leupp *et al*. (2009) observed an increase (linear, $P < 0.004$) in ruminal pH as DDGS level increased from 15 to 60% in the substitution of DR corn.

Although DM intake was restricted to the same level across treatments, replacing DR corn with DDGS increased (linear, $P < 0.01$) NDF, lipids and N intakes and decreased (linear, $P < 0.01$) the starch intake for DDGS *vs*. DRC treatments. The previously mentioned resulted from differences in the chemical composition between DDGS and the replaced corn (Table 2).

Substitution of DR corn with DDGS did not influence ruminal, post-ruminal or the apparent total tract digestion of starch averaging 87.2 ± 2.8, 90.4 ± 3.9 and 98.7 ± 0.6% to ruminal, post-ruminal and total tract digestion, respectively. Those digestion values are in closely agreement with those observed to lambs fed a finishing diet (Green *et al*. 1987; Larson *et al.* 1993; Ortega-Cerrilla & Mendoza 2003). Previous studies (May *et al*. 2008; Corrigan *et al*. 2009) which were conducted with steers, reported that the substitution of DR corn with DDGS did not influence site or extent digestion of starch. The absence of effects with DDGS substitution on starch disappearance is expected. Starch digestion in steers is not greatly affected by starch intake over a range of 1 to 5 kg/d (approximately 2.5 to 12.5 g of starch /kg of BW, Huntington *et al*. 2006). In the present study, the range of starch intake was 9.1 to12 2 g of starch /kg BW.

Ruminal NDF digestion increased (quadratic effect, P < 0.01) with DDGS substitution. DDGS is a source of readily digestible non-forage fiber (Ham *et al*. 1994) and its fiber particles are very small. Therefore, rumen microbes could degrade easily (Bhadra *et al*. 2007). However, the replacement of DR corn with increasing levels of DDGS decreased (linear effect, P < 0.01) the ruminal digestion of OM. This reduction is expected, and is attributable to the relative differences in the ruminal digestion of NDF (48.3%) *vs.* starch (88.2%), and the ruminal indigestibility of dietary fat itself (Zinn 1988). Moreover, it is well known that fat has negative effect on ruminal digestion. Dose-dependent decrease in NDF digestion among the DDGS treatments (10, 20 and 30%) seems to show negative effect of fat.

There were no treatment effects on the flow of MN into the small intestine ($P \geq 0.56$) and ruminal microbial efficiency (flow of MN to the small intestine as a proportion of OM fermented; $P \geq 0.17$). The substitution of DR corn with DDGS tended to increase (linear effect, *P* = 0.07) the flow of N to the small intestine. However, the ruminal N efficiency (flow of non-endogenous N to the small intestine as a proportion of N intake) decreased (linear effect, *P* = 0.02) with increasing DDGS supplementation. Decreased N efficiency with increasing DDGS-N intake is expected due to the proportional decrease in MN contribution as a function of N intake (whereas MN flow to the small intestine was similar across treatments, its contribution to intestinal N supply decreased inversely with N intake). The ruminal digestion of feed N was not affected (*P* ≥ 0.20) by DDGS substitution. Considering the rumen undegradable intake protein (UIP) for DR corn as 55% (NRC 1985b), then the value of UIP for DDGS averaged 44%. This value is less than the current tabular value (73%; NRC 2000). Prior estimates of UIP for DDGS have ranged from 40 to 70% (NRC 2000; Cao *et al*. 2009; Leupp *et al*. 2009; Brake *et al*. 2010; Islas & Soto-Navarro 2011). High variation in UIP values may be due to the source and method of processing (Gunn *et al*. 2009; Hersom *et al*. 2010), and the proportion of solubles returned to grain solid residues in the DDGS mixture (Cao *et al*. 2009). Gilbery *et al*. (2006) observed that at least 87% of the N in corn distiller solubles was degraded in the rumen.

There were no treatment effects (*P* ≥ 0.22) on post-ruminal digestion of OM and N. However, the post-ruminal digestion of NDF increased (quadratic effect, *P* = 0.01), with a maximal level of 30% of DDGS. This effect may occur as a compensation of NDF digestion, which generally occurred in the hindgut when ruminal NDF digestion was low (Gressley *et al*. 2011). Compared to 10 and 20% DDGS levels, a 30% DDGS level showed a decrease (15.2%, Table 3) in the value of NDF ruminal digestion.

Post-ruminal lipids digestion was similar (*P* ≥ 0.56) across treatments, averaging 78.8%. Post-ruminal lipids digestion (LD, %) is largely a function of total lipid intake expressed as grams of lipids/kg BW (LD, % = 83.18 - 4.52LI - $0.68LI^3$, Plascencia *et al*. 2003). In the present study, the lipids content of DDGS diets were 4.7, 5.4 and 5.9% for 10, 20 and 30%

DDGS levels, respectively. According to dry matter intakes for DDGS diets (Table 3) and the average BW of lambs (25.9 kg), the lipid consumptions of the DDGS treatments would equate to 1.24, 1.42, and 1.58 g/kg BW, for the 10, 20 and 30% DDGS diets, respectively. Thus, dietary lipid intake was below of the 1.6 g/kg of BW suggested by Plascencia *et al*. (2003) as being the optimum digestion of lipids.

DDGS levels tended to increase (linear effect, $P = 0.06$) the total tract NDF digestion. This tendency in the digestion of NDF reflects the increased intake of highly digestible NDF from diets containing DDGS. However, consistent with the results of Corrigan *et al*. (2009), the level of DDGS substitution for DR corn decreased (linear effect, $P < 0.01$) the total tract OM digestion. As with ruminal digestion, the reduction in total tract OM digestion was expected, and was largely attributable to relative differences in the total tract digestion of NDF (58%) versus starch (99%). Similar to previous reports in which the consumption of lipids was moderate (i.e. < 6%) (Zinn & Plascencia, 1993, Plascencia *et al*. 1999; Uwituze *et al*. 2010) increases on lipid intake increase fecal excretion of lipids ($P = 0.02$) with no differences in lipids total tract digestion. Consistent with Leupp *et al*. (2009) and Brake *et al*. (2010), the total tract apparent N digestion increased (linear effect, $P = 0.04$) with the level of DDGS substitution. However, this effect may be more of a function of the increased N content of the diet brought about by the replacements (Holter & Reid 1959). Adjusting for metabolic protein fecal loss (NRC 1985a), the true digestion of protein in the present study averaged 91.8% that was similar to the average of previous measurements summarized by the NRC (1985a).

Consistent with effects on total tract OM digestion, the level of DDGS substitution for DR corn tended to decrease (linear effect, $P = 0.08$) the digestibility of GE, however this did not affect ($P \geq 0.25$) the dietary DE (MJ/kg), reflecting the greater gross energy content of DDGS versus DR corn in the replacements (Table 2).

CONCLUSION

Under the conditions of the current experiment, it was concluded that DDGS is appropriate for use as a feed ingredient, and can be included up to 30% in the finishing diets of lambs. As a result of differences in the proportion of starch:NDF content between DDGS and replaced corn, the lower ruminal and total tract digestion of OM was mainly attributable to relative differences in the total tract digestion of NDF versus starch. However, it did not affect dietary DE (Mcal/kg), reflecting the greater gross energy content of DDGS versus corn in the replacements. Accordingly, the comparative DE value of DDGS may be considered similar to the DE value of the DR corn it replaced in the finishing diets fed to lambs.

REFERENCES

Association of Official Analytical Chemists (AOAC). 2000. Official Methods of Analysis, 17th edn. Association of Official Analytical Chemists, Gaithersburg, MD.

Belyea RL, Rausch KD, Tumbleson ME. 2004. Composition of corn and distillers' dried grains with solubles from dry grind ethanol processing. Bioresource Technology **94,** 293–298.

Bhadra R, Muthukumarappan K, Rosentrater KA. 2007. Characterization of chemical and physical properties of distillers dried grain with solubles (DDGS) for value added uses. ASABE annual meeting, paper No. 077009.

Bergen WG, Purser DB, Cline JH. 1968. Effect of ration on the nutritive quality of rumen microbial protein. Journal of Animal Science **27,** 1497-1501.

Berger L, Singh V. 2010. Changes and evolution of corn co-products for beef cattle Journal of Animal Science **88**, E143-E150.

Brake DW, Titgemeyer EC, Jones ML, Anderson DE. 2010. Effect of nitrogen supplementation on urea kinetics and microbial use of recycled urea in steers consuming corn-based diets. Journal of Animal Science **88,** 2729-2740.

Cao ZJ, Anderson JL, Kalscheur KF. 2009. Ruminal degradation and intestinal digestibility of dried or wet distillers grains with increasing concentrations of condensed distillers solubles. Journal of Animal Science **87,** 3013-3019.

Corrigan ME, Erickson GE, Klopfenstein TJ, Luebbe MK, Vander Pol KJ, Meyer NF, Buckner CD, Vanness SJ, Hanford KJ. 2009. Effect of corn processing method and corn wet distiller's grains plus solubles inclusion level in finishing steers. Journal of Animal Science **87,** 3351-3362.

Felix TL, Loerch SC. 2011. Effects of haylage and monensin supplementation on performance, carcass characteristics, and ruminal metabolism of feedlot cattle fed diets containing 60% dried distillers grains. Journal of Animal Science **89,** 2614-2623.

Gilbery TC, Lardy GP, Soto-Navarro SA, Bauer ML, Caton JS. 2006. Effects of corn condensed distillers solubles supplementation on ruminal fermentation, digestion, and in situ disappearance in steers consuming low-quality hay. Journal of Animal Science **84,** 1468-1480.

Green DA, Stock RA, Goedeken FK, Klopfenstein TJ. 1987. Energy value of corn wet milling by-product fed for finishing ruminant. Journal of Animal Science **65,** 1655-1666.

Gressley TF, Hall MB, Armentano LE. 2011. RUMINANT NUTRITION SYMPOSIUM: Productivity, digestion and health responses to hindgut acidosis in cattle. Journal of Animal Science **89,** 1120-1130.

Gunn PJ, Weaver AD, Lemenager RP, Gerrard DE, Claeys MC, Lake SL. 2009. Effects of dietary fat and crude protein on feedlot performance, carcass characteristics, and meat quality in finishing steers fed differing levels of dried distillers grains with solubles Journal of Animal Science **87,** 2882-2890.

Ham GA, Stock RA, Klopfenstein TJ, Larson EM, Shain DH, Huffman RP. 1994. Wet corn distillers byproducts compared with dry corn distillers grains with solubles as a source of protein and energy for ruminants. Journal of Animal Science **72,** 3246–3257.

Hersom MJ, Boss DL, Wagner JJ, Zinn RA, Branine ME. 2010. Alpharma Beef Cattle Nutrition Symposium: Alternative energy sources for beef cattle finishing diets. Journal of Animal Science **88** (E. Suppl.), E121-E122.

Hill FN, Anderson DL.1958. Comparison of metabolizable energy and productive determinations with growing chicks. Journal of Nutrition **64,** 587-603.

Holter JA, Reid JT. 1959. Relationship between the concentrations of crude protein and apparently digestible protein in forages. Journal of Animal Science **18,** 1339-1349.

Huntington GB, Harmon DL, Richard CJ. 2006. Alpharma Beef Cattle Nutrition Symposium: Challenging the Limits of Caloric Intake in Feedlot CattleSites, rates, and limits of starch digestion and glucose metabolism in growing cattle. Journal of Animal Science **84,** E14-E24.

Islas A, Soto-Navarro SA. 2011. Effect of supplementation of dried distillers grains with solubles on forage intake and characteristics of digestion of beef heifers grazing small-grain pasture. Journal of Animal Science **89,** 1229-1237.

Kim Y, Mosier NS, Hendrikson R, Ezeji T, Blascheck H, Dienn B, Cotta M, Dale B, Ladish ML. 2008. Composition of corn dry-grind ethanol by-products: DDGS, wet cake, and thin stillage. Bioresource Technology **99,** 5165-5176.

Klopfenstein TJ, Erickson GE, Bremer VR. 2008. BOARD-INVITED REVIEW: Use of distillers by-products in the beef cattle feeding industry. Journal of Animal Science **86,** 1223–1231.

Larson ME, Stock RA, Klopfenstein TJ, Sindt MH, Shain DH. 1993. Energy value of hominy feed for finishing ruminants. Journal of Animal Science **71,** 1092-1099.

Leupp JL, Lardy GP, Karges KK, Gibson ML, Caton JS. 2009. Effects of increasing level of corn distillers dried grains with solubles on intake, digestion, and ruminal fermentation in steers fed seventy percent concentrate diets. Journal of Animal Science **87,** 2906-2912.

Luebbe MK, Patterson JM, Jenkins KH, Buttrey EK, Davis TC, Clark BE, McCollum III, FT, Cole NA, MacDonald JC. 2012. Wet distillers grains plus solubles concentration in steam-flaked corn-based diets: Effects on feedlot cattle performance, carcass characteristics, nutrient digestibility, and ruminal fermentation characteristics. Journal of Animal Science **90,** 1589-1602.

May ML, Hands MJ, Quinn MJ, Wallace JO, Reinhardt DD, Murray L, Drouillard JS. 2008. Digestibility of dried distiller's grains with solubles in steam-flaked or dry-rolled corn diets. Kansas State University Beef Cattle Research Report of Progress **95,** 80–85.

May ML, Quinn MJ, Reinhardt CD, Murray L, Gibson ML, Karges KK, Drouillard JS. 2009. Effects of dry-rolled or steam-flaked corn finishing diets with or without twenty-five percent dried distillers grains on ruminal fermentation and apparent total tract digestion. Journal of Animal Science **87,** 3630-3638.

McAloon A, Taylor F, Yee W, Ibsen K, Wooley R. 2000. Determining the cost of producing ethanol from cornstarch and lignocellulosic feedstocks. Technical Report (NREL/TP-580-28893). National Renew Energy Laboratory, Golden, CO.

National Research Council (NRC) 1985a. Ruminant nitrogen usage. National Academy Press, Washington, DC.

National Research Council (NRC) 1985b. Nutrient requirement of sheep, 6th ed. National Academy Press, Washington, DC.

National Research Council (NRC) 2000. Nutrient requirements of beef cattle, 7th ed. National Academy of Press. Washington DC.

National Research Council (NRC) 2007. Nutrient requirement of small ruminant. Sheep, Goats, Cervids, and New World Camelids. National Academy Press, Washington, DC.

Ortega-Cerrilla M, Mendoza MG. 2003. Starch digestion and glucose metabolism in the ruminant: a review. Interciencia **28,** 380-386.

Peter CM, Faulkner DB, Merchen NR, Parrett DF, Nash TG, Dahlquist JM. 2000. The effects of corn milling co-products on growth performance and diet digestibility by beef cattle. Journal of Animal Science **78,** 1–6.

Plascencia A, Estrada M, Zinn RA. 1999. Influence of free fatty acid content on the feeding value of yellow grease in finishing diets for feedlot cattle. Journal of Animal Science **77,** 2603-2609.

Plascencia A, Bermudez R, Cervantes M, Corona L, Davila-Ramos H, López-Soto MA, May D, Torrentera N, Zinn RA. 2011. Influence of processing method on comparative digestion of white corn vs. conventional steam-flaked yellow dent corn in finishing diets for feedlot steers. Journal of Animal Science **89,** 136-141.

Plascencia A, Mendoza G, Vazquez C, Zinn RA. 2003. Relationship between body weight and level of fat supplementation on fatty acid digestion in feedlot cattle. Journal of Animal Science **81**, 2653-2659.

Rosentrater, KA. 2006. Some physical properties of distillers dried grains with solubles. (DDGS). Applied Engineering in Agriculture **22,** 589-595.

Rosentrater KA. 2012. Feeding DDGS in other animals, in: Lui, K., Rosentrater, K.A. (Eds.), Distiller grain, production properties and utilization. CRC Press, Boca Raton, FL. Pp. 391-397.

Statistical Analyses System (SAS). 2004. SAS/STAT User'sGuide Version 9.1, SAS Institute, Cary, NC.

Spiehs MJ, Whitney MH, Shuron GC. 2002. Nutrient database for distiller's dried grains with solubles produced from new ethanol plants in Minnesota and South Dakota. Journal of Animal Science **80,** 2639-2645.

Sánchez FC, Salinas MY, Vázquez CMG, Velázquez CGA, Aguilar GN. 2007. Efecto de las prolaminas del grano de maíz (Zea mays L.) sobre la textura de la tortilla. Archivos Latinoamericanos de Nutrición **57**, 295-301(In Spanish).

Srinivasan R, Moreau RA, Rausch KD, Belyea RL, Tumbleson ME, Singh V. 2005. Separation of fiber from distillers dried grains with solubles (DDGS) using sieving and elutriation. Cereal Chemistry **82,** 528-533.

Theurer CB. 1986. Grain processing effects on starch utilization by ruminants. Journal of Animal Science **63,** 1649-1662.

United States Department of Agriculture (USDA).1999. Practical Procedures for Grain Handlers: Inspecting Grain. United States Department of Agriculture – Grain Inspection, Packers, and Stockyards Administration: Washington, D.C. [Cited 13 July 2012] Available from URL: http://151.121.3.117/pubs/primer.pdf

United States Department of Agriculture (USDA). 2010. Energy Balance for the corn ethanol Industry. Agricultural Economic Report No. 846. United States Dep. Agric. Washington, DC.

Uwituze S, Parsons GL, Shelor MK, Depenbusch BE, Karges KK, Gibson ML, Reinhardt CD, Higgins JJ, Drouillard JS. 2010. Evaluation of dried distillers grains and roughage source in steam-flaked corn. Journal of Animal Science **88,** 258-274.

Van Soest PJ, Robertson JB, Lewis BA. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science **74,** 3583–3597.

Zinn RA. 1988. Comparative feeding value of supplemental fat in finishing diets for feedlot steers supplemented with and without monensin. Journal of Animal Science **66,** 213–227.

Zinn RA. 1990. Influence of steaming time on site digestion of flaked corn in steers. Journal of Animal Science **68,** 776-781.

Zinn RA, Plascencia A. 1993. Interaction of whole cottonseed and supplemental fat on digestive function in cattle. Journal of Animal Science **71,** 11-17.

Zinn, R. A., Owens, FN. 1986. A rapid procedure for purine measurement and its use for estimating net ruminal protein synthesis. Canadian Journal of Animal Science **66,** 157-166.

Table 1 Ingredients and composition of experimental diets fed to lambs (% of dry matter)

	Dried distillers grains plus solubles level, %			
Item	0	10	20	30
Ingredient composition (%)				
Dry-rolled corn	74.50	64.50	54.50	44.50
Dried distillers grains with solubles	0.00	10.00	20.00	30.00
Soybean meal	5.00	5.00	5.00	5.00
Sudan grass hay	10.00	10.00	10.00	10.00
Tallow	1.50	1.50	1.50	1.50
Molasses	6.10	6.10	6.10	6.10
Chromium oxide	0.40	0.40	0.40	0.40
Mineral premix	2.50	2.50	2.50	2.50
Chemical composition, (DM basis)				
Crude protein (%)	10.95	12.61	13.98	15.51
Lipids (%)	3.70	4.68	5.38	5.95
NDF (%)	16.04	19.75	22.55	26.12
Gross energy (MJ/kg)	17.45	17.74	18.32	18.41
Calculated net energy (MJ/kg)				
Maintenance	8.66	8.66	8.66	8.66
Gain	5.90	5.90	5.90	5.90

Mineral premix was composed by 64% limestone, 20% NaCl enriched with trace mineral and 16% urea. Mineral premix contained CP, 50%; Calcium, 28%; Phosphorous, 0.55%; Magnesium, 0.58%; Potassium, 0.65%; NaCl, 15%; vitamin A, 1,100 IU/kg; vitamin E, 11 UI/kg; Dietary composition was determined by analyzing subsamples collected and composited throughout the experiment. Accuracy was ensured by adequate replication with acceptance of mean values that were within 5% of each other; Based on tabular net energy (NE) values for individual feed ingredients (NRC, 1985) with the exception of supplemental fat, which was assigned NE_m and NE_g values of 25.1 and 19.87, respectively (Zinn, 1988).

Table 2 Composition and density of DDGS and dry-rolled corn (DRC) used and corresponding tabular values (NRC 2007)

Item	DDGS	DRC	DDGS (NRC, 2007)	DRC (NRC, 2007)
DM (%)	94.2	91.4	90.0	88.0
CP (%)	26.3	9.1	29.0	9.0
NDF (%)	42.7	10.3	43.0	9.0
Starch (%)	4.3	69.4	--	--
Lipids (%)	9.0	3.6	10.6	4.3
Ash (%)	5.6	1.7	6.0	2.0
Gross energy (Mcal/kg)	4.87	4.16	--	--
Density (g/L)	454	702		

DDGS, dry distillers grain with soluble; DRC, dry-rolled corn; DM, dry matter, CP, crude protein; NDF, neutral detergent fiber.

Table 3 Influence of supplementation level of dried distillers grains plus solubles on characteristics of ruminal and total tract digestion in cannulated lambs

	DDGS in diet					Contrast *P*-value		
Item	0%	10%	20%	30%	SEM	Linear	Quadratic	Cubic
Ruminal pH	6.08	6.15	6.25	6.33	0.11	0.15	0.99	0.92
<u>Intake (g/d)</u>								
DM	679	685	684	689	23	0.79	0.98	0.91
OM	634	641	639	646	21	0.74	0.99	0.87
NDF	109a	135b	154c	180d	4	<0.01	0.95	0.49
Starch	319a	272b	250bc	236c	9.9	<0.01	0.15	0.75
N	11.9a	13.8ab	15.3b	17.1c	0.44	<0.01	0.83	0.72
Lipids	24.4a	35.6b	38.7bc	40.9c	1.1	<0.01	0.06	0.19
GE (MJ/d)	11.8	12.1	12.5	12.7	0.40	0.17	0.87	0.86
<u>Flow to duodenum (g/d)</u>								
OM	351	379	382	393	16	0.13	0.64	0.68
NDF	67a	64a	77a	102b	4.5	<0.01	0.02	0.83
Starch	38	36	32	31	5.2	0.30	0.93	0.93
N	14.6	15.6	16.2	17.3	0.92	0.07	0.93	0.83
Nonammonia N	13.9	14.8	15.4	16.4	0.86	0.08	0.99	0.86
MN	8.26	8.67	8.41	7.63	0.96	0.63	0.56	0.97
Feed N	5.61a	6.15a	7.00a	8.73b	0.47	<0.01	0.25	0.79
Lipids	29.8a	37.2b	44.5b	46.6b	3.3	0.02	0.18	0.55
<u>Ruminal digestion (%)</u>								
OM	57.5a	54.4ab	53.4bc	50.8c	0.9	<0.01	0.83	0.41
NDF	38.5a	52.2b	49.7b	43.2ab	2.7	0.38	<0.01	0.37
Starch	88.2	86.9	87.1	87.0	1.7	0.66	0.75	0.83
Feed N	52.8	55.7	54.3	48.7	2.9	0.36	0.20	0.98

Microbial efficiency	23.3	22.9	21.6	19.4	1.9	0.17	0.65	0.98
N efficiency	1.16	1.08	1.00	0.96	0.05	0.02	0.58	0.92
Postruminal digestion (%) leaving abomasum								
OM	66.6	65.7	65.3	62.6	2.1	0.22	0.68	0.77
NDF	19.2ab	9.7a	14.3a	27.8b	2.9	0.06	0.01	0.69
Starch	90.7	90.7	90.8	89.8	1.7	0.74	0.88	0.79
N	77.0	77.2	76.1	77.1	1.2	0.86	0.69	0.56
Lipids	80.5	78.7	79.9	79.2	2.7	0.88	0.32	0.72
Fecal excretion (g/d)								
DM	142a	154ab	130ab	173b	7.6	0.03	0.90	0.71
OM	117a	130ab	133ab	147b	8.3	0.04	0.95	0.60
NDF	53a	58ab	67bc	74c	3.7	<0.01	0.72	0.71
Starch	3.4	3.3	3.1	3.3	0.57	0.83	0.77	0.85
N	3.3	3.5	3.8	3.9	0.21	0.07	0.96	0.84
Lipids	5.8a	7.9b	8.9b	9.7b	1.29	0.02	0.64	0.77
GE (MJ/d)	2.45a	2.66a	2.75a	3.04b	0.15	0.04	0.81	0.67
Total-tract digestion (%)								
DM	78.8a	77.5ab	76.7ab	74.9b	1.1	0.04	0.88	0.75
OM	81.5	79.7	79.3	77.3	1.2	0.06	0.94	0.60
NDF	51.1a	57.2ab	57.1ab	59.2b	2.3	0.06	0.42	0.44
Starch	98.9	98.8	98.8	98.6	0.2	0.36	0.89	0.81
N	72.0	74.4	75.4	76.9	1.3	0.04	0.74	0.79
Lipids	76.2	77.8	77.0	76.4	0.9	0.61	0.47	0.66
DE (%)	79.3	78.0	78.0	76.1	1.0	0.08	0.79	0.55
DE diet (MJ/kg)	13.8	13.8	14.3	13.9	0.21	0.37	0.53	0.25

pH was measured at 4-h posprandium (morning meal); Microbial efficiency is estimated as duodenal MN, g kg^{-1} OM fermented in the rumen; N efficiency is estimated as duodenal non-ammonia N, g g^{-1} N intake; Within rows, means followed by different letters are significantly different at $P < 0.05$

EXPERIMENTO II

Heading title: DDGS as replacement of corn and soybean meal in lambs

Effects of replacing partially dry-rolled corn and soybean meal with different levels of dried distillers grains with solubles on growth performance, dietary energetics, and carcass characteristics in hairy lambs fed a finishing diet

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Artículo enviado al Journal Small Ruminant Research

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Abstract

The objective of this experiment was to determine the effects of replacing partially dry-rolled corn (DRC) and soybean meal (SBM) with different levels (0, 15, 30 and 45%) of dried distillers grains with solubles (DDGS) on growth performance, dietary energetics, carcass characteristics, and visceral mass in hairy lambs fed during 112-d a finishing diet. Lambs (n= 40, average lamb initial weight = 17.27 ± 1.36 kg) were blocked by weight and allotted in 20 pen. The basal diet contained 62 and 18% of DRC and SBM respectively. Dietary treatments consisted of the replacement of the total DRC and SBM in basal diet by DDGS using the following proportions: 1) 0% DDGS for basal diet (DDGS0); 2) 15% DDGS level replacing 15% of DRC and 30% of SBM (DDGS15); 3) 30% DDGS level replacing 30% of DRC and 60% of SBM (DDGS30), and 4) 45% DDGS level replacing 45% of DRC and 90% of SBM (DDGS45). DDGS substitution improved (linear P= 0.04) final weight and average daily gain, but as a consequence of a tendency (P =0.06) to increase dry matter intake (DMI) with DDGS substitution, there were no advantages ($P \geq 0.33$) on gain efficiency, dietary energetic or observed-to-expected DMI. DDGS substitution did not affect dressing percentage and backfat thickness, but increased (linear, $P \leq 0.03$) hot carcass weight and kidney, pelvic and heart fat (KPH) and decreased (linear, P = 0.05) *longissimus* muscle area (LM). There were not treatments effects on carcass composition, but increased DDGS level in substitution tended to linearly decrease as a percentage of cold carcass weight, muscle (P =0.08) and increase carcass fat (linear, P =0.10). There were no effects of substitution with DDGS on wholesale cuts. Replacing corn and SBM with DDGS increased (linear P = 0.03) empty body weight (EBW, as percentage of full weight) but influence on organ weights as a proportion of EBW (g/kg EBW) were small. The estimated net energy of maintenance (MJ/kg) of DDGS was 9.79, 9.62 and 9.50 to DDGS15, DDGS30 and DDGS45, respectively. DDGS is suitable

substitute for a portion of the corn and SBM in a finishing diet, however at high inclusion level tended to decrease LM area and increase KPH.

Keywords: DDGS; Corn; Soybean meal, Finishing diet, Lambs, Performance, Visceral mass.

1. Introduction

During the production process of distillers dry grain with solubles (DDGS), protein, minerals, fat and fiber are concentrated three-fold as co-products when compared with corn. Therefore, DDGS contains approximately 30% CP (73% ruminal undegradable intake protein, UIP), 40% NDF and 11% fat (NRC, 2007), and often costs less than corn (USDA, 2012). The growing supply of DDGS is likely to lower the cost of the feed ingredient, making it more favorable for use as a protein and energy source in the livestock industry. The high potential of the nutritional value of DDGS can be useful for replacing grains (Klopfenstein et al., 2008) or grains plus proteins sources (Depenbusch et al., 2008) in growing-finishing diets of beef cattle. However, it appeared that the feed value of DDGS may vary by level of inclusion (Uwituze et al., 2010) as well as the strategy of ingredients that replaces (Dicostanzo and Wright, 2012). Historically, DDGS has primarily been feed to beef and dairy cattle, swine and poultry (Rosentrater, 2012). Even though DDGS should be appropriate as a feed ingredient for lambs, the feeding value of DDGS in finishing diets fed to lambs is well not defined because only a limited amount of research has evaluated the use of DDG in lamb diets (Huls et al., 2006, Schauer et al., 2008). Huls et al. (2006) reported that feed value of DDGS was similar to a mixture composed by 56% of corn and 44% of SBM, when 17.3% of corn and 100% of SBM were replaced by 22.9% of DDGS in the finishing diet which contained 72.2% and 10.2% corn and SBM, respectively. However, it is known that inclusion levels above 25% may affect the nutritional value of DDGS (Vander Pol et al., 2005). Felix et al. (2012) reported a quadratic effect on ADG in feedlot lambs when corn and soybean meal were replaced by DDGS, being maximal at 20% of inclusion. These researchers argue that chemical composition of DDGS (high content of NDF and fat) are the responsible of the decreases on it feeding value at high levels of inclusion. In opposite, Schauer et al. (2008) reported that lambs could be fed up to 60% DDGS (DM basis), to replace 55% of barley and 5% of soybean meal, without affecting performance and carcass quality, which indicates that the feeding value of DDGS was similar to the proportion of barley and soybean meal replaced in these diets. Because in the most of experiment SBM were totally replaced in DDGS treatments, the relative difference in protein concentration between control diets *vs.* diets supplemented with high level of DDGS was up to 30%. In the same way, the diets generally were not isoenergetic when DDGS partially replace grain and totally replace SBM in diets. Both situations make it difficult to accurately determine the feeding value of DDGS included at high levels in these experiments. Therefore, the purpose of this study was to evaluate, in isoenergetic diets, the feeding value of DDGS included at high levels as partial substitute of corn and SBM, and to test the hypothesis that this DDGS can partially replace corn and SBM in high concentrate diets for finishing hair lambs without affecting growth performance, carcass characteristics and visceral organ mass. Dry distillers grain with solubles is commonly used in feedlot lambs because of its availability throughout Mexico. The USA exports of DDGs to Mexico surged to a record $444 million in 2011 as Mexico became the top market, surpassing China by more than $100 million (USDA, 2012).

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2. Materials and methods

2.1. Diets, animals and experimental design

This experiment was conducted at the Universidad Autónoma de Sinaloa Feedlot Lamb Research Unit, located in the Culiacán, México (24° 46’ 13” N and 107° 21’ 14”W). Culiacan is about 55 m above sea level, and has a tropical climate. All animal management procedures were conducted within the guidelines of locally-approved techniques for animal use and care (NOM-051-ZOO-1995: Humanitarian care of animals during mobilization of animals; NOM-062-ZOO-1995: Technical specifications for the care and use of laboratory animals. Livestock farms, farms, centers of production, reproduction and breeding, zoos and exhibition hall, must meet the basic principles of animal welfare; NOM-024-ZOO-1995: Animal health stipulations and characteristics during transportation of animals, and NOM-033-ZOO-1995, Humanitarian care and animal protection during slaughter process.

Forty Pelibuey × Katahdin (17.27 ± 1.36 kg) crossbred intact male lambs were used in a growth-performance experiment to evaluate the effects of replacing partially soybean meal (**SBM**) and dry-rolled corn (DR) with different levels (0, 15, 30 and 45%) of dried distillers grains with solubles (**DDGS**) on growth performance, dietary energetics, carcass characteristics, and visceral organ mass. Three wk before the experiment started, lambs were treated for endoparasites (Tasasel 5%®, Fort Dodge, Animal Health, México), and injected with $1x10^{6}$ IU vitamin A (Synt-ADE®, Fort Dodge, Animal Health, México). Upon initiation of the experiment, lambs were weighed individually (electronic scale; TORREY TIL/S: 107 2691, TOR REY electronics Inc, Houston TX, USA), before the morning meal and were equally grouped by weight into five uniform weight group and assigned to 5-pen blocks (two lambs per pen). The 16 pens used in the study were 6 m^2 with overhead shade, automatic waterers and 1 m fence-line feed bunks. During a 21-d adaptation period all lambs received the basal diet (no DDGS supplementation, Table 1). Dietary treatments consisted of the replacement of the total of DRC and SBM in basal diet by DDGS using the following proportions: 1) 0% for basal diet (DDGS0); 2) 15% DDGS level replacing 15% of corn and 30% of SBM (DDGS15); 3) 30% DDGS level replacing 30% corn and 60% SBM (DDGS30), and 4) 45% DDGS level replacing 45% corn and 90% SBM (DDGS45). Experimental diets and its chemical composition are shown in Table 1. To maintain the proportion (> 1.5) of Ca:P in diet, limestone was added, replacing molasses cane, at levels of

0.25, 0.50, and 0.75% in diet DDGS15, DDGS30 and DDGS45, respectively. Diets were formulated to be isocaloric but not isonitrogenous, because the protein level increases as the level of DDGS replacing corn and SBM in the diet increased. However, the relative differences between control diet and high level DDGS diet was only 12.6% (17.1 *vs*. 19.6% CP). White corn was used as source of grain in the form of a commercial blend obtained from Mexico. Corn was prepared by passing whole corn through rollers (46 × 61cm rolls, 5.5corrugations/cm; Memco, Mills Rolls, Mill Engineering & Machinery Co., Oklahoma, CA) and machinery that had been adjusted so that the kernels were broken into a approximately bulk density of 0.52 kg/L. The source of DDGS used was a corn DDGS named for its appearance (color) as "Golden" and was obtained in an ethanol production facility with a 0.8% maximal content of sulfur (Pinal Energy LLC, Maricopa, AZ). Soybean meal used was a standard US soybean meal obtained by solvent extraction (Ceres Commodities LCC, Newport, KY). The forage source of diet (sudangrass hay) was ground in a hammer mill (Bear Cat #1A-S**,** Westerns Land and Roller Co., Hastings, NE) with a 3.81cm screen, before incorporation into complete mixed diets. Dietary treatments were randomly assigned to pens within blocks. The experiment lasted 112 days. Lambs were weighed at the beginning of the trial and every 28 days thereafter. Initial BW was reduced 4% to adjust the gastrointestinal fill, and all lambs were fasted (food but not drinking water was withdrawing) during 18 h before recording the final BW. Lambs were allowed *ad libitum* access to dietary treatments. Daily feed allotments to each pen were adjusted to allow minimal (< 5%) feed refusals in the feed bunk. The amounts of feed offered and of feed refused were weighed daily. Lambs were provided fresh feed twice daily at 0800 and 1400 h in a 40:60 proportion (as feed basis). Feed bunks were visually assessed between 0740 and 0750 h each morning, refusals were collected and weighed and feed intake was determined. Adjustments to, either increase or decrease daily feed delivery, were provided at the afternoon feeding.

2.2 Sample analysis

The ingredients (DDGS, corn and soybean meal) and complete diets were subjected to the following analyses: DM (oven drying at 105°C until no further weight loss; method 930.15; AOAC, 2000); CP (N× 6.25, method 984.13; AOAC, 2000); ash (method 942.05; AOAC, 2000); NDF [Van Soest et al., 1991, corrected for NDF-ash, incorporating heat stable α-amylase (Ankom Technology, Macedon, NY) at 1mL per 100mL of NDF solution (Midland Scientific, Omaha, NE)]; ether extract (method 920.39; AOAC, 2000); starch (Zinn, 1990); calcium, (method 927.02; AOAC, 2000) and phosphorus, (method 964.06; AOAC, 2000). Feed and refusal samples were collected daily for DM analysis, which involved oven drying the samples at 105°C until no further weight loss occurred (method 930.15; AOAC, 2000).

2.3. Calculations

The estimations of dietary energetic and expected DMI were performed based on the estimated initial shrunk body weight (SBW), to convert to a SBW basis is assuming that SBW is 96% of full weight (CSIRO, 1990; Cannas et al., 2004), and final body weight. Average daily gains were computed by subtracting the initial BW from the final BW and dividing the result by the number of days on feed. The efficiency of BW gain was computed by dividing ADG by the daily DMI.

The estimation of expected DMI was performed based on observed ADG and average shrunk weight (SBW) according to the following equation: expected DMI, kg/d = (EM/NE_m) + (EG/EN_g), where EM (energy required for maintenance, MJ/d) = [$4.184 \times (0.056 \times SBW^{0.75})$] (NRC, 1985), EG (energy gain, MJ/d) = [$4.184 \times (0.276 \times ADG \times SBW^{0.75})$] (NRC, 1985), NE_m and NE_g are 8.58 and 5.86 MJ/kg, respectively (derived from tabular values based on the ingredient composition of the experimental diet; NRC, 1985), and SBW represent full body weight × 0.96, CSIRO, 1990; Cannas et al., 2004]. The coefficient (0.276) was estimated assuming a mature weight of 113 kg for Pelibuey × Kathdin male lambs (Canton and Quintal, 2007). Dietary NE was estimated by means of the quadratic formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2c},$$

where x = NE_m, a =-0.41EM, b = 0.877 EM + 0.41 DMI + EG, and c = -0.877 DMI (Zinn et al., 2008) and, the results obtained were multiplied by 4.184 to convert to units of MJ.

The estimated net energy of DDGS was performed given that the NE_m values of DR corn and soybean meal are 2.24 and 2.06 Mcal/kg, respectively (NRC, 1985), then the comparative NE_m values for the DDGS may be estimated as follows:

EN_m, Mcal/kg DDGS15 = (((0.775×2.24) + (0.225×2.06)) - ((1.97 - 2.00)/0.8) - ((0.65625×2.24) + (0.15625×2.06)))/0.1875

EN_m, Mcal/kg DDGS30 = (((0.775×2.24) + (0.225×2.06)) - ((1.97 – 2.01)/0.8) - ((0.5375×2.24) + (0.0875×2.06)))/0.375

EN_m, Mcal/kg DDGS45 = (((0.775×2.24) + (0.225×2.06)) - ((1.97- 2.01)/0.8) - ((0.4125×2.24) + (0.025×2.06)))/0.5625

The constants 0.775 and 0.225 represent the proportion of DR corn and SBM on the total participation in basal diet, while the constants 2.24 and 2.06 represent de NE_m of corn and SBM replaced by DDGS. The constant 1.97 represent the EN_m observed to basal diet. The constant 0.80 represent the total percentage of corn and SBM in basal diet. The constants 0.1875, 0.375, and 0.5625 correspond to the proportion of DDGS which replaced corn and SBM in the basal diet. Finally, the constants 0.65625 and 0.15625; 0.5375 and 0.0875, and 0.4125 and 0.025 represent the proportion of corn and SBM in the DDGS replaced diets. The results obtained were multiplied by 4.184 to convert to units of MJ.

2.4. Carcass and visceral mass data

All lambs were harvest on the same day. After sacrifice, lambs were skinned, and the gastrointestinal organs were separated and weighed. After carcasses (with kidneys and internal fat included) were chilled in a cooler at -2 to 1°C for 48 h, the following measurements were obtained: 1) carcass length (maximum distance between the edge of the ischio-pubic symphysis and anterior border of the first rib at its midpoint); 2) carcass depth (maximum distance between the sternum and the back of carcass, at level of sixth thoracic vertebra); 3) leg length (distance from the symphysis pubis to the tarsal-metatarsal joint); 4) body wall thickness (distance between the 12^{th} and 13^{th} ribs beyond the ribeye, five inches from the midline of the carcass); 5) fat thickness perpendicular to the *m. longissimus thoracis* (LM), measured over the center of the ribeye between the 12th and 13th rib; 6) LM surface area, measure using a grid reading of the cross sectional area of the ribeye between 12th and 13th rib, and 7) kidney, pelvic and heart fat (KPH). The KPH was removed manually from the carcass, and then weighed and reported as a percentage of the cold carcass weight (USDA, 1982). Each carcass was split along the vertebrae into two halves. The left side of each carcass was fabricated into wholesale cuts, without trimming, according to the North American Meat Processors Association guidelines (NAMP, 1997). Rack, breast, shoulder and foreshank were obtained from the foresaddle, and the loins, flank and leg from the hindsaddle. The weights of each cut were subsequently recorded. The Carcass composition was assessed using physical dissection by the procedure described by Luaces et al. (2008).

All tissue weights were reported on a fresh tissue basis. Previous data suggests that there is very little variation among fresh and dry weights for visceral organs (Neville et al., 2008). Organ mass was expressed as grams of fresh tissue per kilogram of final empty BW. Final EBW represents the final full BW minus the total digesta weight. Full visceral mass was calculated by the summation of all visceral components (stomach complex + small intestine + large intestine + liver + lungs + heart), including digesta. The stomach complex was calculated as the digesta-free sum of the weights of the rumen, reticulum, omasum and abomasum.

2.5. Statistical analysis

Performance (gain, gain efficiency, and dietary energetics) and carcass data were analyzed as a randomized complete block design. The experimental unit was pen. The MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) was used to analyze the variables. The fixed effect consisted of treatment, and pen as the random component. Whole cuts data and carcass composition were analyzed using the MIXED procedure (SAS Inst. Inc., Cary, NC), in a model with treatment and pen as fixed effects and interaction treatment × pen and individual carcasses within pen by treatment subclasses as random effects, with the final CCW as a covariate when it represented a significant ($P \leq 0.05$) source of variation.

Visceral organ mass data were analyzed using the MIXED procedure (SAS Inst. Inc., Cary, NC), in a model with treatment and pen as fixed effects and interaction treatment × pen and individual carcasses within pen by treatment subclasses as random effects. Treatment effects were tested for linear, quadratic and cubic components of the DDGS supplementation level. Contrasts were considered significant when the P-value was ≤ 0.05, and tendencies were identified when the *P* -value was > 0.05 and ≤ 0.10.

3. Results

As a result of chemical composition of DDGS, DR corn and SBM (Table 2), and given that the proportions of the mixtures of DRC and SBM in control and DDGS supplemented diets contributed with 14.23, 13.58, 12.56 and 10.93% of CP for DDGS0, DDGS15, DDGS30 and DDGS45, respectively. Thus, as DDGS increased and corn grain plus SBM decreased in the diets, crude protein, NDF, and ether extract increased and starch declined (Table 1). Growth performance, dietary energetic, carcass traits and visceral organ mass are shown in Tables 3-6. The DDGS substitution improved (linear $P = 0.04$) final weight and average daily gain, but as a consequence of a tendency ($P = 0.06$) to increase dry matter intake (DMI) with DDGS substitution, there were no advantages ($P \geq 0.33$) on gain efficiency, dietary energetic or observed-to-expected DMI. DDGS substitution did not affect dressing percentage and backfat thickness, but increased hot carcass weight (HCW) and kidney, pelvic and heart fat (KPH) and decreased *longissimus* muscle area (LM). There were not treatments effects on carcass composition, but increased DDGS level in substitution tended to decrease as a percentage of cold carcass weigth, muscle (P =0.08) and increase carcass fat (P =0.10). There were no effects of substitution with DDGS on wholesale cuts. Replacing corn and SBM with DDGS increased (linear P = 0.03) empty body weight (EBW, as percentage of full weight) but influence on organ weights as a proportion of EBW (g/kg EBW) were small. The estimated net energy of maintenance (MJ/kg) of DDGS was 9.79, 9.62 and 9.50 to DDGS15, DDGS30 and DDGS45, respectively.

4. Discussions

4.1 Physical and chemical characteristics of DDGS and replaced corn and soybean meal

The physicochemical composition of DDGS, corn and SBM used in the trial are shown in Table 2. The bulk density of DDGS obtained here corresponds closely to the average bulk density (bulk density varied between 0.389 and 0.502 kg/L) reported previously by Rosentrater (2006). While that bulk density of DR white corn was in close agreement with the targeted 0.57 kg/L. The density of DR corn in the present study was 24% greater than that reported by Plascencia et al. (2011); thus, there was greater coarse-processing of the corn used in the current study. The bulk density of SBM registered here was 0.602 Kg/L. Accordingly to the standards quality of NOPA (The National Oil Processors Association, USA), to soybean meal, bulk density must be in range of 0.57 to 0.64 kg/L, this range may vary by proportion of particle size and soyhulls presents in final product (Molenda et al., 2002).

The nutrient composition of white corn and SBM used in the present experiment was consistent with previous reports (Karr-Lilienthal et al., 2004; Sánchez et al., 2007; Foster et al., 2009; Plascencia et al., 2011). Compared to the values assigned to DDGS by the NRC

(2007), the relative values of CP, NDF, and ash (as 100% of DM) were 0.98, 0.72, and 1.10, respectively. According to the NRC (2007), the main constituent is the NDF, followed by the CP, although this proportion can be changed by the quantity of solubles added during the process (Kim et al., 2008). As a result, much of the variation in the composition of DDGS can be attributed to plant-to-plant differences in the proportions of distillers solubles added during processing (Spiehs et al., 2002; Kim et al., 2008). The average ash content was very similar compared to the results obtained by Spiehs et al. (2002) and Belyea et al. (2004) but was nearly 50% lower than the average obtained by Bhadra et al. (2007).

4.2 Growth performance and dietary energetic

Previous studies evaluating DDGS substitution for corn and SBM did not report effect on feed intake when DDGS was included from levels of 20% (Huls et al., 2006) to 60% (Felix et al., 2012) in finishing diets with soybean hulls as forage source. Similarly, feeding 40% DDGS to lambs that received 10% alfalfa hay did not affect DMI in growing lambs when compared with a corn-based diet (Lodge et al., 1997). But in barley-based diets, Shauer et al. (2006) noted increases on DMI as DDGS increased on diet. The DMI of finishing diets varies with NDF (Galyean and Defoor, 2003) and net energy (NE) content of the diet (NRC, 2007). DDGS is a source of readily digestible non-forage fiber (Ham et al., 1994) and its fiber particles are very small. Therefore, rumen microbes could degrade easily (Bhadra et al., 2007). Thus, in the most of cases, the differences in NDF content of the control diet and DDGS diets have not an important impact on DMI in both, lambs (Lodge et al., 1997, Huls et al., 2006, Zelinsky et al., 2006; Felix et al., 2012) and in feedlot cattle (Al-Suwaiegh et al., 2002; May et al., 2007; Depenbusch et al., 2008; Uwituze et al., 2010).

In prior studies involving lambs (Lodge et al., 1997; Huls et al., 2006; Schauer et al., 2008), substitution of DDGS for DRC and SBM, at levels from 20 to 60% of diet DM did not affect overall ADG or gain efficiency. Huls et al. (2006) reported that feed value of DDGS was similar to a mixture composed by 56% of corn and 44% of SBM, when 17.3% of corn and 100% of SBM were replaced by 22.9% of DDGS in the finishing diet which contained

72.2% and 10.2% corn and SBM, respectively. However, it is known that inclusion levels above 25% may affect the nutritional value of DDGS (Vander Pol et al., 2005). Felix et al. (2012) reported a quadratic effect on ADG in feedlot lambs when corn and soybean meal were replaced by DDGS, being maximal at 20% of inclusion. These researchers argue that chemical composition of DDGS (high content of NDF and fat) are the responsible of the decreases on it feeding value at high levels of inclusion. In opposite, Schauer et al. (2008) reported that lambs could be fed up to 60% DDGS (DM basis), to replace barley and SBM, without affecting performance and carcass quality, which indicates that the feeding value of DDGS was similar to the proportion of barley and SBM replaced in these diets. In the present experiment, the NE content of the DDGS was estimated based on performance. The NE of DDGS (for 15, 30 and 45% level) contained 105, 103 and 101% of the relative NE value of corn. The average NE_m and NE_g values of DDGS were slightly higher (5.6%) with tabular (NRC, 2007) NE_m and NE_g values of 2.18 and 1.50. Similar or superior NE values for DDGS compared to corn is in agreement whit previous reports in lambs (Lodge et al., 1997) and in feedlot cattle (Al-Suwaiegh et al., 2002; Depenbusch et al., 2008; Uwituze et al., 2010). Lodge et al. (2007) determined a 12% greater NE value for DDGS than DR corn when 40% DDGS replace 37% of total corn (control diet contained 78.9% of DRC) and 3% of SBM in finishing diet for lambs. Because lipids contains three times more energy than corn grain (Zinn, 1989), DDGS have greater gross energy content of DDGS versus DRC and SBM in the replacements. Mathematically, based on fat content, DDGS could account for 9% more energy than corn (Larson et al., 1993); however, NE value of fat is dynamic, largely depending on the level of supplementation (Zinn and Plascencia, 2007); thus, the comparative feeding value of DDGS can be affected by level of inclusion. Vander Pol et al. (2005) summarized feeding trials that evaluated performance of cattle fed corn distillers grains and concluded that the energy content of wet distillers grains was higher than that of DRC, but that this difference declined with increasing levels of distillers grains in the diet. In the present experiment, the estimated NE value for DDGS in DDGS15 treatment was 2.34 and declined to 2.27 in DDGS45 treatment. According Plascencia et al. (2003), the NE value of fat is 100% of the tabular value (NRC, 2007) when fat intake not exceeded 1.2 g of fat/kg of BW and declined 1.5% percentage units for each 0.1 g of fat intake/kg of BW under the limit of 1.2 g/kg BW. Another factor is that, at high levels of inclusion (i.e. > 30%), the excess protein of DDGS might decreases the available energy for growth by increasing the energy cost of certain organs that are responsible for dealing with excess protein (Gunn et al., 2009; Salim, 2011). Even though it's necessary consider the effects of removing the starch and replacing it with digestible fiber on animal performance. It is well recognized that subacute acidosis affect negatively growth performance in cattle (Owens et al., 1998). The DDGS contain 94% less starch than DR corn (Table 2); therefore, replacing corn with DDGS may help control subacute acidosis (Lodge et al., 1997; Huls et al., 2006), this can result in better performance and feed efficiency in some experiments in which DDGS replace, at moderated levels, to corn in finishing diets.

4.3 Carcass traits and visceral organ mass

The effects of inclusion of DDGS in diets fed to lambs are contradictory. Similar to our results, Increases on HCW without effect on dressing percentage was reported when DDGS was included up to 60% in finishing diet (Schauer et al., 2008).While, Felix et al. (2012) noted an increase (quadratic effect) of HCW and dressing percentage being maximal at 20% level of inclusion. Back fat thickness (BFT) was increased only in one (Huls et al., 2006) of four reports, the rest of reports, similar to our results, BFT was unaffected by DDGS supplementation. Generally, the LM area remain unchanged when lambs are feeding with diets that contained DDGS (Schauer et al., 2008; Felix et al., 2012), however, a numerical decrease of 4.6% was observed in lambs when 22.9% of DDGS replaced DR corn and SBM

(Huls te al,. 2006). In contrast, no effects on carcass characteristics in Rambouillet wethers were noted with inclusion up to 20% of DDGS in substitution of cottonseed meal in a sorghum-based finishing diet (Whitney and Braden, 2010). Similar, in feedlot cattle, Leupp et al. (2009) did not observed differences on carcass characteristics when they replaced 30% of DRC with DDGS in finishing ration. In the same manner, Ham et al. (1994) and Lodge et al. (1997) reported no differences in 12th-rib fat thickness, quality grade, or yield grade in steers fed corn or sorghum DDGS, respectively, compared with DRC. Typically, increases on intake of dietary fat has increased KPH (Zinn, 1988; Brand and Anderson, 1990; Plascencia et al., 1999); thus, increases on KPH in cattle fed diets with high levels of DDGS is expected. In agreement with the above, in the present experiment a positive linear effect was observed to KPH amount in relationship to DDGS level. However, Felix et al. (2012) reported a quadratic effect (P = 0.03) of dietary DDGS inclusion on KPH. Lambs fed 20% DDGS had the greatest amount of KPH, while lambs fed 60% DDGS shown lower values KPH than controls (2.62 vs. 3.07). Excluding the present experiment and the report of Felix et al. (2012), no data of KPH in lambs fed diets supplemented with DDGS are available. In heifers fed a stem-flaked corn based diets a linear increase in the KPH value was observed from the level of inclusion of 30% of DDGS (Gordon et al., 2002). While, Corrigan et al. (2009) observed that KPH increased quadratically on steers fed a steam-flaked corn diets as WDGS level increased, greater responses observed when 15 and 25.7% WGDS was fed. However, in feedlot cattle, inclusion up to 40% of DDGS has not shown an impact on KPH (Depenbusch et al., 2008; Leupp et al., 2009; Uwituze et al., 2010).

Although Whitney and Braden (2010) did not measure carcass protein, similarly to our results, total percentage of fat in carcass linearly increased as DDG increased in the diet when lambs were fed a finishing sorghum-based diet. In contrast, in lambs fed a DRC-based diet the LM fat decreased linearly with increasing DDGS inclusion in the diet (Felix et al., 2012). The reason for the inconsistent responses in carcass composition is not clear but appears to be related with energy and protein level among the control and DDGS diets. The diets were isoenergetic and isoproteic in the experiment of Whitney and Braden (2010), while in the experiment of Felix et al (2012) were not. Apparently, calories from DDGS differently affected the energy partitioning and site of fat deposition, as result of level of inclusion as well as the strategy of ingredients that replaces. Until recently, the effect of DDGS in finishing lambs on yield of wholesale cuts has been limited and published research in this area scarce. Even thought, similar to our results, Felix et al. (2012) did not observed effect on the trimmed cuts in lambs when compared control diet with other DDGS diets.

In relation to the organ weights of GIT as response to DDGS suplemenattion, the liver weight (gram and gram per kilogram of BW) of steers, did not differ when DDGS was included up to 50% in finishing diet contained whole corn (Salim, 2011). According to Sainz et al (1997), it seems that liver weight responds mainly to energy-yielding nutrients and amino acids. While, the total mass of the forestomachs responded to diet type rather than intake, increasing with dietary fiber content (Sun et al., 1994) and the main factor that influencing intestinal weight seemed to be dietary fiber (Sainz et al., 1997) and protein intake (Jhonson et al., 1990). As mentioned previously, DDGS is a source of readily digestible non-forage fiber (Ham et al., 1994) and its fiber particles are very small which favors a rapid passage rate. Additionally the diets of the present experiment were formulated to be isoenergetic and the differences on protein concentration among diets were small (Table 1).

5. Conclusions

In finishing diets to lambs, the feeding value of DDGS is similar than the dry-rolled corn (~2.30 Mcal/kg ENm), thus the NE of DDGS is slightly greater (~6%) than reported in current standards (NRC, 2007). This feeding value decreases as inclusion level of DDGS increases beyond 30%. DDGS is suitable substitute for a portion of the dry-rolled corn and

SBM in a finishing diet; however, at high levels of inclusion, tends to decrease LM area and increase KPH. An additional consideration is that the use of DDGS as an alternative feed for fattening lambs depends on the relative price of DDGS, corn and protein supplements.

References

Al-Suwaiegh, S., Fanning, K.C., Grant, R.J., Milton, C.T., Klopfenstein, T.J., 2002. Utilization of distiller's grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. J. Anim. Sci. 80, 1105–1111.

AOAC, 2000. Official Methods of Analysis. Association of Official Analytical Chemists. Gaithersburg, MD.

Belyea, R.L., Rausch, K.D., Tumbleson, M.E., 2004. Composition of corn and distillers' dried grains with solubles from dry grind ethanol processing. Bioresource Technol. 94, 293–298.

Bhadra, R., Muthukumarappan, K., Rosentrater, K.A., 2007. Characterization of chemical and physical properties of distillers dried grain with solubles (DDGS) for value added uses. ASABE annual meeting, paper No. 077009.

Brandt, Jr. R.T., Anderson, S.J., 1990. Supplemental fat source affects feedlot performance and carcass traits of finishing yearling steers and estimated diet net energy value. J. Anim. Sci. 68, 2208-2216.

Cannas, A., Tedeschi, L.O., Fox, D.G., Pell A.N., Van Soest, P.J., 2004. A mechanistic model for predicting the nutrient requirements and feed biological values for sheep. J. Anim. Sci. 82,149-169.

Canton, J.G., Quintal, J.A., 2007. Evaluation of growth and carcass characteristics of pure Pelibuey sheep and their cross with Dorper and Katahdin breeds. J. Anim. Sci. 85 (Suppl. 1), 581. (Abstr.).

Corrigan. M. E., Erickson, G.E., Klopfenstein, T.J., Luebbe, M.K.,Vander Pol, K.J., Meyer, N.F.,Buckner, C,D., Vanness, S.J., Hanford, K.J., 2009. Effect of corn processing method and corn wet distiller's grains plus solubles inclusion level in finishing steers. J. Anim. Sci. 87, 3351-3362.

CSIRO, 1990. Feeding Standards for Australian Livestock.Ruminants. G. E. Robards, G.E., Radcliffe, J.C. (Eds.). CSIRO Publications, East Melbourne, Australia.

Depenbusch, B. E., Loe, E.R., Quinn, M. J., Corrigan, M. E., Gibson, M.L., Karges, K.K., Drouillard, J.S., 2008b.Corn distillers grains with solubles derived from a traditional or partial fractionation process: Growth performance and carcass characteristics of finishing feedlot heifers. J. Anim. Sci. 86, 2338-2346.

Dicostanzo, A., Writhe, C.L., 2012. Feeding Ethanol Coproducts to Beef Cattle. In: Lui, K., Rosentrater, K.A. (Eds.), Distiller grain, production properties and utilization. CRC Press, Boca Raton, FL. Pp. 391-397.

Felix, T.L., Zerby, H.N., Moeller, S.J., Loerch, S.C., 2012. Effects of increasing dried distillers grains with solubles on performance, carcass characteristics, and digestibility of feedlot lambs. J. Anim. Sci. 90, 1356-1363.

Foster, J.L., Adesogan, A.T., Carter, J.N., Blount, A.R., Myer, R.O., Phatak, S.C., 2009. Intake, digestibility, and nitrogen retention by sheep supplemented with warm-season legume haylages or soybean meal. 87, 2899-2905.

Galyean,M.L., Defoor, P.J., 2003. Effects of roughage source and level on intake by feedlot cattle. J. Anim. Sci. 81 (E. Suppl. 2), 8-16.

Gordon, C. M., Drouillard, J.S., Gosch, J., Sindt, J.J.. Montgomery, S.P., Pike, J.N., Kessen, T.J., Supizio, M. J., Spire, M.F., Higgins, J.J., 2002. Dakota gold brand dried distillers grains with solubles: Effects on finishing performance and carcass characteristics.

Pages 27–29 in Kansas State University Cattleman's Day Report of Progress No. 890. Kansas State Univ., Manhattan.

Gunn, P. J., Weaver, A.D., Lemenager, R.P., Gerrard, D.E., Claeys, M.C., Lake, S.L., 2009. Effects of dietary fat and crude protein on feedlot performance, carcass characteristics, and meat quality in finishing steers fed differing levels of dried distillers grains with solubles. J. Anim. Sci**.** 87, 2882-2890.

Ham, G. A., Stock, R.A., Klopfenstein, T.J., Larson, E.M., Shain, D.H., Huffman, R.P., 1994. Wet corn distillers byproducts compared with dry corn distillers grains with solubles as a source of protein and energy for ruminants. J. Anim. Sci.72, 3246–3257.

Huls, T.J., Bartosh, A.J., Daniel, J.A., Zelinsky, R.D.,. Held, J.,Wertz-Lutz, A.E., 2006. Efficacy of dried distiller's grains with solubles as a replacement for soybean meal and a portion of the corn in a finishing lamb diet. Sheep and Goat Res. J. 21, 30-34.

Johnson, D. E., Johnson, K.A., Baldwin, R.L., 1990. Changes in liver and gastrointestinal tract energy demands in response to physiological workload in ruminants. J. Nutr. 120, 649−655.

Karr-Lilienthal, L.K., Merchen, N.R., Grieshop, C.M., Flahaven, M.A., Mahan, D.C., Fastinger, N.D., Watts, M., Fahey, Jr. G.C., 2004. Ileal amino acid digestibilities by pigs fed soybean meals from five major soybean-producing countries. J. Anim. Sci. 82, 3198-3209.

Kim, Y., Mosier, N.S., Hendrikson, R., Ezeji, T., Blascheck, H., Dienn, B.,Cotta, M., Dale, B., Ladish, M.L., 2008. Composition of corn dry-grind ethanol by-products: DDGS, wet cake, and thin stillage. Bioresource Technol. 99, 5165-5176.

Klopfenstein T. J., Erickson, G.E., Bremer, V.R., 2008. BOARD-INVITED REVIEW: Use of distillers by-products in the beef cattle feeding industry. J. Anim. Sci. 86, 1223–1231.

Larson, M.E., Stock, R.A., Klopfenstein, T.J., Sindt, M.H., Shain D.H., 1993. Energy value of hominy feed for finishing ruminants. . J. Anim. Sci. 71, 1092-1099.

Leupp, J. L., Lardy, G.P., Bauer, M.L., Karges, K.K., Gibson, M.L., Caton J.S., Maddock, R.J., 2009. Effects of distillers dried grains with solubles on growing and finishing steer intake, performance, carcass characteristics, and steak color and sensory attributes. J.Anim. Sci. 87, 4118-4124.

Lodge, S.L., Stock, R.A., Klopfenstein, T.J., Shain, D.H., Herold, D.W., 1997. Evaluation of wet distillers composite for finishing ruminants. J.Anim. Sci. 75, 44-50.

Luaces, M.L., Calvo, C., Fernández, B., Fernández, A., Viana, J.L., Sánchez, L., 2008. Ecuaciones predictoras de la composición tisular de las canales de corderos de raza gallega. Arch Zootec. 57, 3-14.

May, M. L., Drouillard, J.S., Quinn, M.J., Walker, C.E., 2007. Wet distiller's grains with solubles in beef finishing diets comprised of steam-flaked or dry-rolled corn. Kansas State University Beef Cattle Research 2007. Report of Progress 978, 57–59.

Molenda, M., Montross, M.D., Horabik, J., Ross, I.J., 2002. Mechanical properties of corn and soybean meal. Transactions of the ASAE. 45, 1929-1936.

NAMP, 1997. The Meat Buyers Guide. North American Meat Processor Association. Weimar, TX.

Neville, B.W., Schauer, C.S., Karges, K., Gibson, M.L., Thompson, M.M., Kirschten, L.A., Dyer, N.W., Berg P.T., Lardy, G.P., 2010. Effect of thiamine concentration on animal health, feedlot performance, carcass characteristics, and ruminal hydrogen sulfide concentrations in lambs fed diets based on 60% distillers dried grains plus soluble. J. Anim. Sci. 88, 2444-2455.

NRC, 1985. Nutrient requirement of sheep. (6th Rev. Ed.). National Academy Press, Washington, DC.

NRC, 2007. Nutrient requirement of small ruminant. Sheep, Goats, Cervids, and New World Camelids. National Academy Press, Washington, DC.

Owens, F.N., Secrist, D.S., Hill, W.J., Gill, D.R., 1998. Acidosis in cattle: A review. J. Anim. Sci. 76, 275-286.

Plascencia, A., Estrada, M., Zinn, R.A., 1999. Influence of free fatty acid content on the feeding value of yellow grease in finishing diets for feedlot cattle. J. Anim. Sci. 77, 2603-2609.

Plascencia, A., Mendoza, G., Vazquez, C., Zinn, R.A., 2003. Relationship between body weight and level of fat supplementation on fatty acid digestion in feedlot cattle. J. Anim. Sci. 81, 2653-2659.

Plascencia, A., Bermudez, R., Cervantes, M., Corona, L., Davila-Ramos, H., López-Soto, M.A., May, D., Torrentera, N., Zinn, R.A., 2011. Influence of processing method on comparative digestion of white corn vs. conventional steam-flaked yellow dent corn in finishing diets for feedlot steers. J. Anim. Sci. 89**,** 136-141.

Rosentrater, K.A., 2006. Some physical properties of distillers dried grains with solubles. (DDGS). Appl. Eng. Agric. 22, 589-595.

Rosentrater, K.A., 2012. Feeding DDGS in other animals. In: Lui, K., Rosentrater, K.A. (Eds.), Distiller grain, production properties and utilization. CRC Press, Boca Raton, FL. Pp. 391-397.

Sainz, R.D., Bentley, B.E., 1997. Visceral organ mass and cellularity in growth-restricted and refed beef steers. J. Anim. Sci. 75:1229-1236.

Salim, H.S., 2011. Nutritional, physiological and environmental effects of feeding distiller's grains plus soluble to feedlot cattle. Dissertation PhD. University of Guelph, Canada.

Sánchez, F.C., Salinas, M.Y., Vázquez, C.M.G., Velázquez, C.G.A., Aguilar, G.N., 2007. Efecto de las prolaminas del grano de maíz (Zea mays L.) sobre la textura de la tortilla. Arch. Latinoam. Nutr. 57, 295-301 (In Spanish).

Schauer, C.S., Stamm, M.M., Maddock, T.D., Berg, P.B., 2008. Feeding dried distillers grains with solubles as 60 percent of lamb finishing rations results in acceptable performance and carcass quality. Sheep and Goat Res. J. 23, 15-19.

Spiehs, M. J., Whitney, M.H., Shuron, G.C., 2002. Nutrient database for distiller's dried grains with solubles produced from new ethanol plants in Minnesota and South Dakota. J. Anim. Sci. 80, 2639-2645.

Sun, W., Goetsch, A.L., Forster Jr., L.A., Galloway Sr., D.L., Lewis, Jr., P.K., 1994. Forage and splanchnic tissue mass in growing lambs. Br. J. Nutr. 7, 141−151.

USDA, 1982. Official United States Standards for Grades of Carcass Lambs, Yearling Mutton and Mutton Carcasses. Agric. Marketin.

USDA, 2012. International Agricultural Trade Report. Foreing Agriculture Service. United States Department of Agriculture. Accesed on September 4, 2012. http://www.fas.usda.gov/info/IATR/IATR_DDG_June_2012.pdf

Uwituze, S., Parsons, G.L., Shelor, M.K., Depenbusch, B.E., Karges, K.K., Gibson, M.L., Reinhardt, C.D., Higgins, J.J., Drouillard, J.S., 2010. Evaluation of dried distillers grains and roughage source in steam-flaked corn. J. Anim. Sci.88, 258-274.

Vander Pol, K., Erickson, G., Klopfenstein,T.J., Greenquist, M., 2005. Effect of level of wet distillers grains on feedlot performance of finishing cattle and energy value relative to corn. J.Anim. Sci. 83(Suppl. 2),55. (Abstr.).

Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74, 3583–3597.

Whitney, T.R., Braden, K.W., 2010.Substituting Corn Dried Distillers Grains for Cottonseed Meal in Lamb Finishing Diets: Carcass Characteristics, Meat Fatty Acid Profiles, and Sensory Panel Traits. Sheep and Goats Res. J. 25, 49-56.

Zelinsky, R., Daniel, J., Held, J., 2006. The Effect of Corn or distillers' grain with solubles to sheep, Supplemented with Dried Distillers Grain with Solubles (DDGS) on Finishing Lamb Performance and Carcass Merit. South Dakota State University Cooperative Extension Service, Sheep Res. Rpt.Pp3.

Zinn, R. A., 1988. Comparative feeding value of supplemental fat in finishing diets for feedlot steers supplemented with and without monensin. J. Anim. Sci. 66, 213-227.

Zinn, R.A., 1990. Influence of steaming time on site digestion of flaked corn in steers. J. Anim. Sci. 68, 776-781.

Zinn, R.A., Barreras, A., Owens, F.N., Plascencia, A., 2008. Performance by feedlot steers and heifers: ADG, mature weight, DMI and dietary energetics. J. Anim. Sci. 86, 1-10.

Zinn, R.A., Plascencia, A., 1993. Interaction of whole cottonseed and supplemental fat on digestive function in cattle. J. Anim. Sci. 71**,** 11-17.

Table 1 Ingredients and composition of experimental diets fed to lambs (% of dry matter)

	Dried distillers grains plus solubles level, %			
Item	0	15	30	45
Ingredient composition (%)				
Dry-rolled corn	62.00	52.50	43.00	33.00
Dried distillers grains with solubles	0.00	15.00	30.00	45.00
Soybean meal	18.00	12.50	7.00	2.00
Sudan grass hay	10.00	10.00	10.00	10.00
Molasses cane	7.50	7.25	7.00	6.75
Limestone	0.00	0.25	0.50	0.75
Trace mineral salt	2.50	2.50	2.50	2.50
Chemical composition, (DM basis)				
Crude protein (%)	17.10	17.74	18.70	19.56
Ether extract (%)	2.98	3.90	4.79	5.77
NDF (%)	15.98	19.90	23.76	27.22
Starch	44.02	39.46	32.44	26.68
Ca	0.79	0.89	1.01	1.12
P	0.38	0.50	0.62	0.72
Calculated net energy (Mcal/kg)				
Maintenance	2.00	2.00	2.00	1.99
Gain	1.35	1.35	1.35	1.35

Mineral premix contained: CP, 50%; Calcium, 28%; Phosphorous, 0.55%; Magnesium, 0.58%; Potassium, 0.65%; NaCl, 15%; vitamin A, 1,100 IU/kg; vitamin E, 11 UI/kg; Dietary composition was determined by analyzing subsamples collected and composited throughout the experiment. Accuracy was ensured by adequate replication with acceptance of mean values that were within 5% of each other; Based on tabular net energy (NE) values for individual feed ingredients (NRC, 1985) with the exception of supplemental fat, which was assigned NE_m and NE_g values of 6.00 and 4.75, respectively (Zinn, 1988).

Table 2 Composition of DDGS, dry-rolled corn (DRC) and soybean meal used

Item	DDGS	DRC	Soybean meal
DM (%)	94.2	91.4	91.7
CP (%)	29.7	9.1	49.4
NDF (%)	33.2	10.3	12.1
Starch (%)	4.3	69.4	2.7
Ether extract (%)	9.8	3.6	2.8
Ash (%)	5.7	1.7	7.5
Ca	0.17	0.03	0.32
P	0.88	0.26	0.62
Density (g/L)	491	598	602

DDGS, dry distillers grain with soluble; DRC, dry-rolled corn; DM, dry matter, CP, crude protein; NDF, neutral detergent fiber

Table 3. Treatment effects on growth performance and dietary energy in drylot hairy lambs fed different levels of DDGS.

	DDGS level, %					*P* value		
Item	0	15	30	45	SEM	Linear	Quadratic	Cubic
Days on test	112	112	112	112				
Pen replicates	5	5	5	5				
Live weight, Kg [c]								
Initial	17.29	17.26	17.25	17.29	0.04	0.95	0.43	0.84
Final	44.28	44.31	46.47	47.47	1.09	0.03	0.57	0.61
Total gain, kg	26.99	27.05	29.22	30.18	1.09	0.04	0.69	0.51
ADG, kg	0.241	0.242	0.261	0.270	0.009	0.04	0.69	0.51
DMI, g/d	1.017	1.008	1.074	1.112	0.031	0.06	0.26	0.44
DMI, g/kg $^{0.75}$	79.06	77.29	80.24	81.92	1.69	0.08	0.36	0.45
G:F, kg/kg	0.237	0.240	0.243	0.243	0.004	0.33	0.76	0.88
Dietary NE, MJ/kg								
Maintenance	8.24	8.37	8.41	8.41	0.12	0.34	0.71	0.97
Gain	5.52	5.61	5.65	5.69	0.11	0.34	0.71	0.97

Observe to expected dietary NE ratio[d]								
Maintenance	0.99	1.00	1.00	1.01	0.015	0.91	0.25	0.73
Gain	0.98	0.99	1.00	1.00	0.019	0.84	0.22	0.63
Observe to expected daily DM intake	1.01	0.99	0.98	0.98	0.018	0.92	0.15	0.50

Table 4. Treatment effects on dressing percentage and carcass characteristics.

	DDGS level, %					*P* value		
Item	0	15	30	45	SEM	Linear	Quadratic	Cubic
HCW, kg	26.59	27.13	28.48	28.84	0.53	<0.01	0.86	0.47
Dressing percentage	60.12	61.23	60.31	60.75	0.56	0.71	0.56	0.21
CCW, kg	26.05	26.53	28.08	28.31	0.52	<0.01	0.81	0.42
LM area, cm^2	12.32	12.37	11.30	11.14	0.45	0.05	0.82	0.34
Fat tickness, cm	0.24	0.21	0.22	0.22	0.015	0.50	0.33	0.64
KPH, %	2.17	2.04	2.48	3.10	0.29	0.03	0.22	0.76
Carcass composition, kg								
Muscle	5.87	6.25	6.01	6.11	0.16	0.51	0.41	0.21
Fat	2.46	2.27	2.42	2.44	0.14	0.90	0.40	0.39
Bone + scraps	1.93	1.96	2.07	2.02	0.06	0.17	0.51	0.38
Carcass composition, % CCW								
Muscle	22.55	23.54	21.42	21.61	0.60	0.08	0.51	0.07
Fat	8.51	8.00	9.23	9.33	0.47	0.10	0.55	0.22
Bone + scraps	7.43	7.40	7.40	7.15	0.22	0.40	0.63	0.77
Muscle to bone ratio	3.03	3.18	2.92	3.02	0.09	0.46	0.83	0.08
Muscle to fat ratio	2.45	2.83	2.49	2.58	0.18	0.97	0.42	0.17

Table 5. Treatment effects on yield of wholesale cuts.

	DDGS level, %					*P* value		
Item	0	15	30	45	SEM	Linear	Quadratic	Cubic
Wholesale cuts weight, kg								
Loin	0.992	0.991	1.081	0.964	0.054	0.96	0.27	0.21
Rack	1.010	0.966	0.947	1.006	0.028	0.81	0.09	0.68
Leg	3.221	3.383	3.373	3.310	0.077	0.49	0.16	0.73
Breast	1.197	1.097	1.135	1.106	0.049	0.32	0.46	0.35
Shoulder	1.861	1.995	1.839	1.940	0.061	0.79	0.79	0.07
Flank	0.794	0.758	0.779	0.766	0.026	0.62	0.67	0.43
Foreshank	1.499	1.502	1.463	1.420	0.066	0.24	0.63	0.86
Wholesale cuts, % of HCW								
Loin	8.84	8.74	9.73	8.79	0.43	0.67	0.35	0.14
Rack	9.12	8.63	8.52	9.16	0.27	0.99	0.06	0.77
Leg	29.04	30.08	30.26	29.99	0.53	0.26	0.23	0.85
Breast	10.67	9.63	10.27	10.03	0.36	0.45	0.28	0.14
Shoulder	16.97	17.79	16.43	17.38	0.51	0.94	0.88	0.08
Flank	7.14	6.70	6.98	6.87	0.26	0.66	0.55	0.36
Foreshank	13.53	13.33	13.13	12.74	0.37	0.16	0.80	0.91

Table 6. Treatment effects on visceral organ weight.

Item	DDGS level, %				SEM	P value		
	0	15	30	45		Linear	Quadratic	Cubic
Full final weight, kg	46.12	46.16	49.19	49.45	1.20	0.03	0.93	0.30
GIT fill, kg	4.28	4.44	3.79	3.83	0.29	0.16	0.84	0.24
Empty body weight, kg	43.45	43.29	43.94	43.90	0.29	0.16	0.84	0.26
Empty body weight, % of full weight	90.95	90.65	92.06	92.01	0.44	0.03	0.78	0.12
Full viscera, kg	10.08	10.08	9.55	9.75	0.27	0.26	0.70	0.33
Organs , g/kg EBW								
Stomach complex	33.69	32.69	31.92	31.73	0.82	0.09	0.62	0.92
Small intestine	18.80	19.69	18.35	18.62	0.45	0.37	0.51	0.08
Large intestine	34.49	33.05	36.00	36.66	1.37	0.12	0.43	0.29
Liver	20.40	19.05	19.52	20.11	0.51	0.62	0.09	0.64
Heart/lungs	23.49	22.74	23.00	24.01	0.69	0.50	0.19	0.95
visceral fat	22.01	19.96	22.83	24.57	1.99	0.25	0.34	0.50