Productive performance of hair lambs fed fresh orange (*Citrus sinensis*) residues substituting sorghum (*Sorghum vulgare*) grains

Zamira Villanueva[1], M. A. Ibarra[1], P. Zárate[1], F. Briones[1], O. S. Escamilla[2], A. González[1] and E. Gutiérrez[3]

[1]*Universidad Autónoma de Tamaulipas, Centro Universitario "Adolfo López Mateos" S/N, Cd. Victoria Tamaulipas, México*

[2]*Instituto Tecnológico de Cd. Victoria, Apartado Postal 175, Cd. Victoria Tamaulipas, México.*

[3] *Universidad Autónoma de Nuevo León, C. Francisco Villa S/N, Escobedo, Nuevo León*

Email: agr1952@hotmail.com

The effect of substituting in the diet sorghum grain for fresh orange residue was assessed in Dorper lambs, crossbred and confined. Its repercussion on weight gain, feed intake and feeding conversion was appraised. Twenty lambs with 15.75 + 4.3 kg of initial weight were used, assigned to a completely randomized design with four treatments (T1: 15 % fresh orange residue + 85 % concentrated feed; T2: 20 % fresh orange residue + 80 % of concentrated feed; T3: 25 % fresh orange residue + 75 % concentrated feed and T4: 30 % fresh orange residue + 70 % concentrated feed). Five repetitions per treatment were conducted. Besides, analysis of covariance for initial weight was also conducted. Significant differences ($P < 0.05$) between treatments were observed for daily weight gain (238.4, 220.4, 210.2 and 209.2 g), daily feed intake (1.35, 1.22, 1.07, 0.970 kg) and feeding conversion (5.2, 4.8, 4.3 and 3.8 kg/kg of increase) for the lambs consuming rations of 15, 20, 25 and 30 % of fresh orange residue, respectively. The fresh orange residue had CP content of 6.0 % and *in vitro* DM digestibility of 72.3 %. The results indicate that its inclusion in lambs' rations can be of up to 30 %, without diminishing the animals' productivity, reducing the ration costs translated into higher benefit.

Key words: *weight gain, feed intake, feeding conversion*.

The fresh orange residue, formed by peel, bagasse and seeds, is obtained from juice processing plants in great volumes. It can be used during critical forage production seasons and become an alternative for the nutrients seasonal deficit imposed by the production systems based on forages. Besides, it contributes to reducing the environmental pollution from managing the industrial by-products with high humidity content, making its storage difficult.

As consequence of the industrial process of these fruits, after the juice obtainment, 45 to 60 % of the residue remains, composed of 60-65 % peel, 30-35 % pulp and 0-10 % seeds (Viuda *et al*. 2008). It may be used in cattle feeding as an energy source, acceptable especially for ruminants (Bueno *et al*. 2002 and Romero 2010).

Tamaulipas state, located in the northeast of Mexico, is characterized by a citrus produce area for juice industry. The region reaches a production of 7 049 431 t (SIAP 2010), from which great amount of by-products are generated, such as the fresh orange residue, considered a good source of fiber, highly fermentable and digestible in the rumen, and contributing with important energy substrates for ruminal activity (Rojas-Bourrillón *et al*. 2001). This is due to its high pectin content, one of the most rapidly degraded carbohydrates in the rumen, while its energy value compares with that of the grains used in the integral and balanced rations (Sudweeks 1977).

Bampidis and Robinson (2006), Caparra *et al*. (2007) and Dihigo *et al*. (2008) indicated that citrus residue is a by-product rich in soluble carbohydrate in neutral detergent and is an available source for the growth of microorganisms in the rumen. Therefore, the fresh orange residue can be used as cereals substitute in ruminants' rations.

In order to study the fresh orange residue potential as carbohydrate source in ruminants' diet, the substitution of sorghum grains by this by-product in the rations of confined lambs was assessed.

Materials and Methods

Location. The study was conducted in the Zootechnical Post "Eng. Herminio García González" and in the Animal Nutrition Laboratory of the Engineering and Science Faculty from the Autonomous University of Tamaulipas (UAT), in Güemez municipality, in Tamaulipas state, located in km 23, National Road Victoria Monterrey, in northeast Mexico. The production unit is located at 23º 45' 10" north latitude and 98º 59' 05" west longitude, at 145 m a.s.l. The weather is semi-dry and warm. The annual average temperature and rainfall is of 22 ºC and 700 mm, respectively. In the summer, the wind is from the south and from the north in winter (INEGI 2009).

Experimental units. Twenty crossbred lambs from a sheep herd of the FIC, UAT, were selected. The animals' health was assessed to discard any disease. Later, they were removed of parasites with ivermectin (Ivermax® 1%) and the eight-way vaccine (Bobac®) was applied. The lambs reached initial average weight of 15.75 + 4.3 kg. They were distributed according to treatments in individual pens under roof, with concrete floor and

free access to feed and water.

Treatments and feeding. The treatments assessed were four rations with 85, 80, 75 or 70 % of concentrated feed, elaborated with sorghum bales, sorghum grains, soybean, molasses, pre-mixture of vitamins and minerals and 15, 20, 25 of 30 % of fresh orange residue, composed of orange pulp, shell and seeds from the juice extraction process. The rations were designed to substitute the sorghum grain by fresh orange residue, in proportions of 23, 31, 38 and 46 % respectively (table 1).

The concentrated feed for each diet was mixed separately. The ingredients were added according to the proportions indicated (table 1), except the fresh orange residue, added daily when feeding the lambs.

The ground sorghum grain and the fresh orange residue were determined the concentrations of DM, CP, ash, EE and nitrogen-free extract (NFE), according to the procedures of AOAC (2001). The NDF, ADF, cellulose, hemicellulose and lignin were counted according to van Soest (1994). Likewise, the technique described by Tilley and Terry (1963) was used for assessing the *in vitro* DM digestibility. The ruminal fluid of sheep fed a diet similar to the feeding assessed was used as inoculum. It was obtained through suction with a hand pump. A buffer solution, prepared according to the methodology of McDougall (1948) was used.

The ME was calculated with the *in vitro* DM digestibility, using the conversion formulas of the National Research Counsil (2007). Previous to the beginning of the experimental phase, the animals were submitted to an adaptation to the rations for 15 d. Later, data were collected during 60 d. Each lamb received daily 2.0 kg of feed, according to is treatment. The rejected feed was daily removed and weighed. An assessment of the cost-benefit per kg of lamb per treatment was made and the income costs used in each ration were determined.

Measured variables. The daily weight gain, feed intake on dry basis and feed conversion were calculated. The first was calculated according to the weight at the beginning of the experimental phase and later, every 15 d, with previous fast of 12 h. The feed intake was estimated daily, when weighing the amount of feed offered minus that rejected. The feed conversion was obtained by dividing the feed intake into the total daily weight gain obtained.

Statistical analysis. The variables were evaluated through a general linear model for a random experimental design, with the following model:

$$Y_{ij} = \mu + T_i + \beta_j X_{ij} + \varepsilon_{ij}$$

$i = 1, \ldots\ldots t$

$j = 1, \ldots\ldots, r$

where:

Y_{ij} = response variable in the j-th repetition of the i-th treatment

μ = general mean

T_i = Effect of the i-th ration

X_{ij} = initial weigth of the j-th lamb of the ration

β = regression coefficient relating Y_{ij} with the variable X_{ij}

ε_{ij} = random error

The data were analyzed with the software SAS 9.1® (2003) for a completely random design and covariance with the initial weight as co-variable.

Results and Discussion

Table 2 shows the values of the chemical composition of the fresh orange residue and that of the sorghum grains used in the experimental rations.

According to Rincón *et al*. (2005), the fresh orange residue is a product with high content of carbohydrates and low CP (table 2). Cuevas (2011) informed similar values for CP, CF, EE, NFE and ME (7.9, 11.2, 2.0, 74.0 % and13.3 MJ/kg DM, respectively) and Ojeda *et al*. (2008) for DM, CP and CF (14.8, 7.6 and 14.3%, respectively). However, González (2007) reported higher values (15.1%) for CP. In the case of NDF and ADF, inferior values to those referred by Quintero *et al*. (2008) were found, who reported 32.7 and 20.9 %, respectively. Meanwhile, Martínez *et al*. (2008) reported 4.7 % for ash, superior to that obtained in this study. The *in vitro* DM digestibility of the fresh orange residue (72.3%) was similar to that refered by Basurto and Tejada (1992) and Macedo *et al*. (2007), who reported values from 75.0 to 80.0 %. The energy values of the rations provides the necessary ME to cover the nutritional requirements for

Table 1. Composition (%) of the experimental rations (Basis DM).

Ingredients	Concentrate + 15 % fresh orange residue	Concentrate + 20 % fresh orange residue	Concentrate + 25% fresh orange residue	Concentrate + 30 % fresh orange residue
Sorghum bale	10.0	10.0	10.0	10.0
Fresh orange residue	15.0	20.0	25.0	30.0
Ground grain of sorghum	49.5	44.4	39.4	34.4
Soybean paste	12.0	12.0	12.0	12.0
Sugarcane molasses	10.0	10.0	10.0	10.0
Vitamins and minerals	2.5	2.5	2.5	2.5
Urea	1.0	1.0	1.0	1.0

Table 2. Chemical composition and *in vitro* DM digestibility (%) of the fresh orange residue and sorghum grain

Indicator	Fresh orange residue	Sorghum grain
Dry matter	21.9	90.2
Crude protein	6.0	11.2
Crude fiber	16.2	4.3
Ether extract	2.4	3.2
Nitrogen-free extract	72.2	76.4
Ash	3.2	4.9
NDF	22.7	45.2
ADF	17.1	26.4
Cellulose	11.7	13.1
Hemicellulose	18.0	9.7
Lignin	1.7	2.1
In vitro DM digestibility	72.3	68.0
ME (MJ/kg of DM)	10.9	10.0

the lambs (10.9 MJ of ME/kg), according to the requirements of the NRC (2007).

Table 3 presents the results for the daily weight gain, feed intake and feed conversion. The significant differences ($P < 0.05$) were determined when proving that the lambs fed with 15 and 20 % of fresh orange residue obtained higher daily weight gain and feed intake. They diminished systematically as the level of fresh orange residue increased in the rations. This can be attributed to the humidity content of the fresh orange residue. The same tendency was shown for the feed conversion. The co-variance analysis showed significant effect ($P < 0.05$) for the initial weight under the conditions of this experiment.

The results of this study in daily weight gain were lower than those reported by Martínez and Fernández (1980), who reported 312, 272 and 234 g/animal/d of daily weight gain in lambs fed with rations with 0, 30 and 60 % of citrus residue, respectively. However, they were similar t those of Macías-Cruz *et al*. (2010). These authors obtained values of 230, 238, 250, 260, and 170 g in lambs fed rations where the fresh orange residue substituted the buffel hey in 40, 30, 20, 10 and 0 %, respectively. Morales *et al*. (2010) confirmed no effect on the daily weight gain (245 and 238 g) in lambs fed rations with 0 and 10 % of citrus residues, respectively. On the other hand, these values were superior to those of Caparra *et al*. (2007) for groups of lambs fed rations with 0, 30 and 45% of citrus residues (183, 188 and 165 g/d).

There were significant differences ($P < 0.05$) in the feed intake for the different levels of fresh orange residue (table 3), with higher values when it was included in 15 and 20 %, respectively. This performance was similar to that reported by Basurto and Tejada (1992), who did not observe differences for feed intake in lambs fed rations with 0, 15, 30 and 45 % of fresh orange residue, respectively. This result was similar to that recorded by López (2007), who noticed that as the citrus level increased in the ration, the DM intake diminished. Macías-Cruz *et al*. (2010) found different situation in lambs, when referring square performance in consumption values of 1.13, 1.22, 1.34 and 1.32 kg of feed in dry basis for treatments including 0, 15, 30 and 45 % of fresh orange residue, respectively.

There were significant differences ($P < 0.05$) for feed intake. It was better in the ration with 30 % of fresh orange residue. This is due to the high content of highly digestible carbohydrates of the residue, giving it

Table 3. Results of the productive performance of lambs fed rations with different proportions (%) of fresh orange residue in substitution of sorghum

Indicator	Concentrated feed + 15% fresh orange residue	Concentrated feed + 20% fresh orange residue	Concentrated feed + 25% fresh orange residue	Concentrated feed + 30% fresh orange residue	SE+
Daily weight gain (g d^{-1})	238.4[a]	220.4[a]	210.2[b]	209.2[b]	0.032
Daily feed intake (DM) (kg d^{-1})	1.35[a]	1.22[b]	1.07[c]	0.97[d]	0.054
Feeding conversion	5.20[b]	4.80[b]	4.30[b]	3.80[b]	0.91
Cost/kg of lamb ($)	17.52[a]	12.70[b]	10.89[b]	8.30[b]	2.08

[a, b] different letters within the same row indicate significant differences (Tukey $P < 0.05$)

Table 4. Chemical composition of the experimental rations used to assess the effect of substituting grain sorghum by fresh orange residue

Fresh orange residue %	DM, %	CP, %	CF, %	EE, %	Nitrogen-free stratum, %	Ash, %	NDF, %	ADF, %	Hemicellulose, %	Cellulose, %	Lignin, %	ME, MJ/kg	DM *in vitro* digestibilitybility, %
15	84.8	15.0	13.2	2.1	67.8	2.3	34.1	14.9	23.1	6.2	1.5	12.1	83.2
20	82.0	14.9	14.5	2.1	66.5	2.0	31.6	14.3	23.4	2.5	1.4	12.5	86.6
25	81.0	13.2	16.2	2.2	66.4	2.0	33.1	14.3	23.7	2.7	1.4	12.9	87.5
30	79.4	12.5	16.7	2.1	67.0	1.7	34.0	13.6	25.8	2.1	1.4	13.8	92.7

high degradability. Macías-Cruz *et al*. (2010) informed values of 5.4, 6.2, 5.5, 4.8 and 6.6 in rations for lambs, where the fresh orange residue substituted the buffel hey in levels of 40, 30 20 10 and 0 %, respectively. The chemical composition of the rations with different levels of fresh orange residue is shown in table 4. The ration including 15 % of fresh orange residue had higher CP content that decreased as the fresh orange residue was higher, showing, at the same time, the lowest CF content. For the contents of EE, NFE, NDF, ADF, HEM and lignin, the values were similar in the different rations and were not for the cellulose. In this case, the rations including 15 % of fresh orange residue reached higher values than those with 20, 25 and 30 %.

In respect to the *in vitro DM* digestibility, the results showed its increase when increasing the fresh orange residue level in the ration, up to obtaining 92.1 % for the treatment with 30 % of the orange residue. This could be attributed to the high degradability of the NDF and the carbohydrates rich in pectin. These conditions have beneficial effect compared with that recorded in the supplementation with feeds rich in starch or any other carbohydrates (Bampidis and Robinson 2006).

These results agree with those of Macías-Cruz *et al*. (2010), who reported that in lambs'diets with 30 and 40 % of fresh orange residue, there was higher digestibility (80.6 and 84.2 %) than those including lower level. This, according to Macedo *et al*. (2007), is attributed to the high content of pectin in the fresh orange residue, translated into higher degradability in the rumen.

The cost of the rations offered showed significant differences ($P < 0.05$) for the different treatments. In order to increase 1 kg of lamb, there was higher cost for the treatment including 15 % of fresh orange residue. There was a decrease as the residue increased, with lower cost for the ration with 30 % of fresh orange residue.

It is concluded that the fresh orange residue may be used as useful alternative in the feeding of confined lambs during the fattening process up to 30 %, substituting the sorghum grain. This would represent a diminishing of 48 % in the feeding costs per kg of lamb.

References

AOAC 2001. Official Methods of Analysis. Ass. Off. Anal. Chem. Washington, D. C. USA. Pp. 399-406

Bampidis, V.A. & Robinson, P.H. 2006. Citrus by-products as ruminants feeds: a rewiew. Animal Feed Sci. Tech. 128:175

Basurto, G.R. & Tejada, H.1992. Digestibilidad aparente de la pulpa deshidratada de limón. Comparación de métodos para estimarla. Técnica Pecuaria 30:13

Bueno, M.S., Ferrari, E., Blanchini, D., Leinz, F.C. & Rodríguez, F. 2002. Effect of replacing corn with dehydrated citrus pulp in diets of growing kids. Small Rum. Res. 46:179

Caparra, P., Fotti, F., Scerra, M., Sinatra, M.C. & Scerra, V. 2007. Solar-dried citrus pulp as an alternative energy source in lamb diets: effects on growth and carcass and meat quality. Small Ruminal Res. 68:303

Cuevas, M.M. 2011. Una alternativa para temporadas de escasez de pastos: cáscara de naranja, opción alimentaria para ganado. Instituto Tecnológico Superior de Misantla, Veracruz, México. Available: http://www.engormix.com/MA-agricultura/pasturas/articulos/ escasez-de-pastos-t3373/089-p0.htm. [Consulted: 28/04/12]

Dihigo, L.E., Savón, L., Hernández, Y., Domínguez, M. & Martínez, M. 2008. Physico-chemical characterization of mulberry (*Morus alba*), citrus (*Citrus sinensis*) pulp and sugarcane (*Saccharum Officinarum*) meals for the feeding of rabbits. Cuban J. Agric. Sci. 42:65

González, P.N.E. 2007. Elaboración de galletas de bagazo de naranja. Thesis Graduate. Química en Alimentos. Universidad Autónoma del Estado de Hidalgo. México. Pp. 57- 60

INEGI 2009. Instituto Nacional de Geografía e Informática. Prontuario de información geográfica municipal de los Estados Unidos Mexicanos. Available: http://www.inegi.org.mx/sistemas/mexicocifras/datos-geograficos/28/28013.pdf. [Consulted: 25/10/11].

López, Z.J. 2007. Elaboración y validación de una dieta balanceada para la engorda de ovinos, a partir de harina de bagazo de naranja. Graduate Thesis. Instituto de Ciencias Básicas e Ingeniería. Universidad Autónoma del Estado de Hidalgo, Pachuca de Soto, Hidalgo, México. Pp. 55-58

Macedo C.A.B., Mizubuti, I. & Moreira, B.Y.F. 2007 Comportamento ingestivo de ovinos recebendo dietas com diferentes níveis de bagaço de laranja em substituição à silagem de sorgo na ração. Revista Brasileira de Zootecnia. 36:1910

Macías-Cruz, U., Quintero-Elisea, L., Avendaño-Reyes, A., Correa-Calderón, F. D., Álvarez-Valenzuela, S. A., Soto-Navarro, F. A., Lucero-Magaña, A. González, R. 2010. Buffel grass (*Cenchrus ciliaria* L.) substitution for orange pulp on intake, digestibility, and performance of hairsheep lambs. Trop. Anim. Health and Prod. 42:223

McDougall, E.I. Studies on ruminant saliva. 1948. The composition and output of sheep`s saliva. Biochem. J. 43:99

Martínez, J. & Fernández J. 1980. Citrus pulp in diets for fattening lambs. Animal Feed Sci. & Tech. 5:11

Martínez, M.J., Chongo, G.B., Jordán, V.H., Hernández, S.N., Fontes, M.D., Lezcano, M.Y. & Cubillas, L.N. 2008. Características nutritivas de los hollejos húmedos de naranja (*Citrus sinensis* cv. Valencia) mantenidos en estibas. Técnica Pecuaria 46:183

Morales, H., Stuart, J.R., González, J., Gutiérrez, E., Bernal, H., & Colín, J. 2010. Productive performance and dynamics of blood metabolites in Pelibuey lambs, fed cereals, dehydrated citrus pulp and urea. Cuban J. Agric. Sci. 44:129

NRC. National Research Council. 2007. Nutrient requirements of Dairy Cattle. Washington, DC. USA. National Academy Press. p. 381

Ojeda F., Cáceres, O. Montejo, I. & Martín, G.J. 2008. Estudio de la acción del probiótico sorbial en los indicadores nutricionales de hollejos de naranja conservados con diferentes materiales absorbentes. Pastos y Forrajes 31:3

Quintero, E., Macías, C.U., Correa, C.A., Avendaño, R.L., Zárate, F.P., Hinojosa, I.M.A, Lucero, M.F.A. & González, R.A. 2008. Características bromatológicas de cítricos con diferentes días de almacenamiento. XXXVI Reunión Anual Asociación Mexicana de Producción Animal. p. 221

Rincón, A.M., Vázquez, A.M. & Padilla, F.C. 2005. Composición química y compuestos bioactivos de las harinas de cáscara de naranja (*Citrus sinensis*), mandarina (*C. reticulata*) y toronja (*C. paradissi*) cultivadas en Venezuela. Archivos Latinoamericano de Nutrición. 55:3

Rojas-Bourrillón, A., Gamboa, L., Villarreal, M., Viquez, E., Castro R. & Poore, M. 2001. La sustitución de maíz por pulpa de cítricos deshidratada sobre la producción y composición láctea de vacas encastadas Holstein en el trópico húmedo de Costa Rica. Revista Agronomía Costarricense. 25:45

Romero, D.P. 2010. Utilización de la cáscara de naranja fresca y morera como alternativas de alimentación en ganado de doble propósito. Reuniones de Investigación e Innovación Agroalimentaria y Forestal en México. Campeche, México. p. 124

Tilley, J. M. & Terry, R.A. 1963. A two stage technique for the *in vitro* digestion of forage crops. J. Br. Grassland Soc. 18:104

SAS. 2003. Statiscal Analysis Systems. Version 9.1 para Windows. User's guide Statistics. Statistical Analysis System Institute. Inc. Cary, NC.

Sistema de Información Agroalimentaria y Pesquera. 2010. Secretaría de Agricultura, Ganadería y Recursos Pesqueros. SAGARPA. Available: http://www.siap.gob.mx/index.php?option=com_content&view=article&id=343:se-espera-crecimiento-en-la-produccion-de-citricos-para2010&catid=72infogramas & Itemid = 422. [Consulted: 22/08/12]

Sudweeks, E.M. 1977. Digestibility by sheep of diets of citrus pulp, corn or soybean mill feed with three forages. J. Dairy Sci. 60:1410

Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant (2nd Ed.). Cornell University Press. Ithaca, New York. p. 476

Viuda, M., Ruiz, Y., Fernández-López, J. & Pérez, A. 2008. Antifungal activity of lemon (*Citrus lemon* L), mandarin (*C. reticulata* L.), grapefruit (*C. paridisi* L) and orange (*C. sinensis*) vs. essential oils. Food Control 19:1130

Received: May 16, 2012