Chemical treatment of maize stover with urea

Muñoz F., Joy M., Andueza J.D., Alibés X.

in

Antongiovanni M. (ed.).
Exploitation of Mediterranean roughage and by-products

Zaragoza : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 17

1998
pages 33-38

Chemical treatment of maize stover with urea

F. Muñoz, M. Joy, J.D. Andueza and X. Alibés
Unidad de Tecnología en Producción Animal, Servicio de Investigación Agroalimentaria (SIA), Diputación General de Aragón (DGA), P.O. Box 727, 50080 Zaragoza, Spain

SUMMARY - The purpose of this work is describing the use of the urea treatment to improve the nutritive value of maize stover and the main factors which influence the effectiveness of the treatment: dose, moisture, temperature, and source of ureases. Treatments with urea improve the nutritive value of ligno-cellulosic residues, but the response of the maize stover to the treatment is very variable according to literature. Animal response to urea treatments is similar to that observed with anhydrous ammonia treatment. This response is optimum with moderately yielding animals. Animals need supplementation in those periods of high requirements.

Key words: Crop residues, nutritive value, doses, moisture, temperature, urease.

RESUME - *"Traitement chimique à l'urée des tiges de maïs". Le propos de ce travail est de décrire l'utilisation du traitement à l'urée pour améliorer la valeur nutritive des tiges et feuilles de maïs, ainsi que les principaux facteurs qui influencent l'efficacité du traitement : dose, humidité, température, et source d'uréases. Les traitements à l'urée améliorent la valeur nutritive des résidus lignocellulosiques, mais la réponse des tiges et feuilles de maïs au traitement est très variable selon la littérature. La réponse animale aux traitements à l'urée est similaire à celle qui est observée avec le traitement à l'ammoniac anhydre. Cette réponse est optimale avec des animaux à rendement modéré. Les animaux nécessitent une supplémentation pendant les périodes de grands besoins.*

Mots-clés : *Résidus des cultures, valeur nutritive, doses, humidité, température, uréase.*

Introduction

Several methods (physical, chemical and biological) have been studied to improve the nutritive value of by-products. Chemical treatment has been well studied too (Jackson, 1977; Kloppfenstein, 1978; Sundstøl, 1988a,b), being the ammonia treatment one of the most used, which can be made with anhydrous-ammonia aqueous ammonia or urea.

Urea treatment is a well-demonstrated method of improving the nutritive value of low quality roughage, by the effect of the ammonia ion on the cell wall. The ammonia ion swells and hydrolyses the cell wall carbohydrates and phenolic monomers (Chesson *et al.*, 1983). The final effect is an increase of the digestibilities of dry matter (DM) and cell wall, of the nitrogen content and of DM intake (Oji *et al.*, 1977).

In Spain about 483,000 ha are annually devoted to maize growing can estimated that the available stover represents more than 2.5 millions tons of dry matter. Only a small portion of this amount of maize stover is used as food for ruminants mainly due to its low nutritive value. It can be used successfully as the main ingredient of diet with a minimum supplementation to feed small ruminants with low requirements.

During several years the Servicio de Investigación Agroalimentaria (SIA) in Zaragoza (Spain) has studied the effect of urea treatment on the nutritive value of straw or maize stover. Also the most favourable conditions under which the treatment should be carried on have been determinate.

Urea treatments

The effect of the urea treatment on the nutritive value of roughage is the result of two processes which occur within the treated forage: (i) ureolysis which turns urea into ammonia through and enzymatic reaction that requires the presence of the urease enzyme; and (ii) the effect of ammonia on the cell walls on the forage. Several factor such as urea doses, moisture, temperature, affect the effectiveness of urea treatment.

Urea dose

The dose of alkali to be applied is one of the most important factor to determine the efficiency of treatment, and it is related to the moisture content, temperature and time reaction (Cloete and Kritzinger, 1984; Williams *et al.*, 1984a; Muñoz *et al.*, 1991; Joy *et al.*, 1994). Besides of the above mentioned factors, there are another factors which also influence the effectiveness of the dose of urea. As it is well known, the initial nutritive value of maize stover determines the effect of urea treatment. Leask and Daynar (1973) found that the physiological maturity of crop has influences on the *in vitro* dry matter digestibility (IVDMD) of stover. Also there are differences in the chemical composition and IVDMD between the plants components, leaf, stalks, and ear, (Andueza *et al.*, 1994), which at the same time are affected by the maturity of harvest (Perry and Compton, 1977).

The capacity of the forage to react to alkaline treatment depends on the botanical family, the species and the varieties to which the maize stover belongs. Andueza *et al.*, 1994, observed that morphological parts of the maize stover responded differently to the urea treatment, being the greatest response for leaves.

Several studies have been developed to determine the effect of increasing, the dose of urea on maize stover. A summary is showed in the Table 1. In general terms, a dosage of 3-4% urea can be considered sufficient when the treatment is carried out with a moisture contents of 30% (Joy *et al.*, 1992). In relation to that, Chermiti *et al.* (1989) concluded that the increase of the dose of urea does not produce a lineal increase of the *in vitro* digestibility, having a maximal effect when the dose of urea applied is about 6% on cereal straw.

Table 1. Organic matter digestibility (OMD), voluntary intake coefficients and digestible organic matter intake (DOMI) of maize stover

Treatment		OMD	Intake	DOMI	References
Maize stover	–	63.7	–	–	Demarquilly, 1979
Maize stover	*In vivo*	54.2	29.2	14.6	Alibés *et al.*, 1984
Maize stover	*In vivo*	53.2	33.2	16.6	Alibés *et al.*, 1984
Maize stover	*In vivo*	50.5	30.5	14.2	Joy *et al.*, 1992
Maize stover treated with urea (4%)	*In vivo*	54.3	33.4	16.4	Joy *et al.*, 1992
Maize stover treated with urea (4%)	*In vivo*	49.5	43.5	19.4	Joy *et al.*, 1992
Maize stover treated with urea (4%)	*In vivo*	57.0	55.3	28.8	Joy *et al.*, 1992
Maize stover	*In vivo*	52.2	–	–	Alibés and Tisserand, 1990
Maize stover treated with urea	*In vivo*	53.3	–	–	Alibés and Tisserand, 1990
Maize stover	–	57.0	–	–	INRA, 1988
Maize stover	*In vivo*	56.7	36.2	18.7	Chenost *et al.*, 1991
Maize stover treated with urea (6%)	*In vivo*	53.1	32.9	16.0	Chenost *et al.*, 1991
Maize stover treated with urea (8%)	*In vivo*	60.8	23.0	12.4	Chenost *et al.*, 1991
Maize stover	*In vitro*	51.7	–	–	Kiangi *et al.*, 1981
Maize stover treated with urea	*In vitro*	54.0	–	–	Kiangi *et al.*, 1981
Maize stover	*In vivo*	56.0	57.9	28.9	Oji and Mowat, 1979
Maize stover	*In vitro*	46.8	–	–	Fernández-Rivera and Kloppfenstein, 1989
Maize stover treated with urea (6%)	*In vitro*	59.6	–	–	Dias-da-Silva *et al.*, 1988

Moisture

The moisture contents of the treatment is an important factor because urea must suffer a ureolysis reaction to be transformed into ammonia ion, which acts as alkali. In this reactions the presence of water is required. Dias-da-Silva *et al.* (1988) and Muñoz *et al.* (1991) showed that the increase of moisture contents improves the rate of ureolysis. However, the effect of the increase of moisture content is not lineal, being higher when carried out at low content (Ibrahim *et al.*, 1986; Muñoz *et al.*, 1991; Joy *et al.*, 1992). According to Besle *et al.* (1990) when the moisture content increases over 30% the effect of urea treatment is improved mainly due to the increase of the ureolysis rate and therefore there is a greater amount of ion ammonia. Other studies have observed that an increase of moisture over 40% does not show any effect (Muñoz *et al.*, 1991) but a minimum of 25% is required (Andueza *et al.*, 1994). If the moisture content is lower than 25%, the rate of ureolysis can be severely reduced and therefore no improve of the nutritive value of maize stover is recorded (Muñoz *et al.*, 1991; Joy *et al.*, 1992).

Temperature

In the anhydrous ammonia treatment, Alibés *et al.* (1984) concluded that the high temperatures favour optima results and good nitrogen retention. The limited effectiveness of some treatment, either ammonia or urea (Mandell *et al.*, 1988; Mann *et al.*, 1988), has been attributed to low temperatures. An important interaction between temperature and time of retention has been observed (Waagepetersen and Vestergaard-Thomsen, 1977; Cloete *et al.*, 1983; Sundstøl and Coxworth, 1984), which means that the effect of the temperature can be partially compensated by an increase of the time of reaction (Cloete *et al.*, 1983; Sundstøl and Coxworth, 1984). Muñoz *et al.* (1991) treated maize stover with 3% of urea at 5, 15 and 25°C during two months and found that temperature increase was not decisive in determining the rate of ureolysis, although a great nitrogen retention in maize stover was observed. Wanapat *et al.* (1996) concluded that the optimal temperature to reach the complete rate of ureolysis was between 30-60°C depending on the kind of urease enzyme. It seems that when temperature is low (5°C), the rate of ureolysis is not enough to affect the nutritive value of roughage (Cloete and Kritzinger, 1984; Benahmed and Dulphy, 1985; Besle *et al.*, 1990).

Time of reaction

The duration of the alkali treatment *per se* is longer than the ureolysis process. The time required in order that the urea treatment could be effective depends on several factors such as: moisture content, dose of urea applied, temperature and source of urease. In general, in temperate countries, it is recommended that at least 3 weeks are necessary. Muñoz *et al.* (1991) observed an increase in organic matter digestibility in maize stover treated with 6% of urea, during the 45 days of treatment. Having an improvement of organic matter digestibility of 5 points in two weeks of duration of the treatment.

Urease

The enzyme urease needed for urea hydrolysis comes from either the forage itself or from any other external source added to the forage. Ground soya bean is the most widespread used source of urease because of its good ureasic activity. The advantage of adding depends mainly on the amount and activity of the urease forage. Therefore, results found are not consistent and the way to add this enzyme has not been established. The addition of urease is interesting when we are looking for a way to reduce the moisture content of treatment, thus making easier the application of urea. Muñoz *et al.* (1991), treated 1.5 kg DM of the corn stover with commercial urea (46% N) at 5, 15 and 25°C temperature and 15, 20, 30 and 40% moisture with addition or not of a source of urease. The application of an external urease did not cause significant response ($P > 0.05$) in any of the studied parameters. Yameogo-Bougouma *et al.* (1993) found that urea treatment of wet straws (33% DM) does not need a supply of exogenous urease, because the environment conditions favour the growth of microorganisms with ureasic activity. Joy *et al.* (1992) showed that the application of soya bean meal as a source of urease, has a positive effect on digestibility and voluntary intake as consequence of the increase of the rate of ureolysis when the urea was applied in solid form. According to Williams *et al.* (1984a,b), Dias-da-Silva *et al.* (1988) and Yameogo-Bougouma *et al.* (1993) this result is related to the small amount of urease enzyme secreted by the telluric ureolytic bacteria when the moisture content is low.

Supplementation

The aim of the supplementation should be to offer enough amounts of concentrate to maximize the utilization of the roughage, and therefore improving the performance of the animal. The supplementation of ligno-cellulosic residues with variable amounts of concentrate modify the intake and the animal performance, depending on several factors, such as the kind of forage (Lamb and Eadie, 1979; Bocquier *et al.*, 1987), source of concentrate (Fahmy *et al.*, 1984; Faverdin *et al.*, 1991), and the relation forage: concentrate (Berge and Dulphy, 1985; INRA, 1988). The level of digestible organic matter intake observed with maize stover treated with urea is lower or slightly lower than the energy requirement for the animal maintenance, 26 g DOMI kg^{-1} $BW^{0.75}$ (INRA, 1978). When animal are in a productive phase (most part of the animal life production) the diet based on the maize stover must be supplemented. If the roughage had been treated, the required supplementation is energetic. Andueza *et al.* (1995) studied the effect of increasing the amount of barley in the diet based on maize stover, from 0 to 600 g at 200 g intervals. He found that the maize stover intake decreased as barley supply increased with a rate of substitution of 0.47 g kg^{-1}. Mbatya *et al.* (1985) and Castrillo *et al.* (1995), also found similar rate of substitution when urea treated straw was supplemented with 0, 25 and 50% of diet with meadow hay. Albertí and Castro (1984) found a rate of substitution of 0.61 g kg^{-1} in steers fed with ammonia-treated maize stover and supplemented with barley. In this case the maize stover intake was 81 and 65 g kg^{-1} $BW^{0.75}$ when supplemented with 2 and 4 kg of barley, respectively.

For social-economical reasons supplementation of roughage should be composed by local feed resources in order to avoid the excessive use of classical concentrates. Supplementation to the roughage diets as maize stover must not be applied when the animal performance is low, although the supplementation of minerals and vitamins must be always correct. When the animal has a low requirement of energies, as it is in the case of non-pregnant or non-lactating ewes or oats, roughage without supplementation can be offered as diet.

References

Albertí, P. and Castro, P. (1984). Cañote de maíz tratado con amoniaco en dietas de cebo de terneros. Efecto del nivel de suplementación. *ITEA*, 56: 47-53.

Alibés, X., Muñoz, F. and Faci, R. (1984). Anhydrous ammonia-treated cereal straw for animal feeding. Some results from Mediterranean area. *Anim. Feed Sci. Technol.*, 10: 239-246.

Alibés, X. and Tisserand, J.L. (eds) (1990). *Tableaux de la valeur alimentaire pour les ruminants des fourrages et sous-produits d'origine méditerranéenne.* Options Méditerranéennes, Series B No. 4.

Andueza, J.D., Muñoz, F. and Joy, M. (1994). Efecto del tratamiento con urea sobre las distintas fracciones morfológicas del cañote de maíz. In: *Actas de la XXXIV Reunión Científica de la Sociedad Española para el Estudio de los Pastos*. SEEP, Santander, pp. 343-347.

Andueza, J.D., Muñoz, F., Joy, M. and Sebastián, I. (1995). Influencia de la suplementación con cebada sobre la digestibilidad e ingestión de cañote de maíz tratado con urea. *ITEA Vol. Extra*, 16: 33-35.

Benahmed, H. and Dulphy, J.P. (1985). Note sur la valeur azotée de fourrages pauvres traités par l'urée ou l'ammoniac. *Ann. Zootech.*, 34(3): 335-346.

Berge, Ph. and Dulphy, J.P. (1985). Etude des interactions entre fourrage et aliment concentré chez le mouton. II. Factors de variation de la digestibilité. *Ann. Zootech.*, 40: 227-246.

Besle, J.M., Chenost, M., Tisserand, J.L., Lemoine, J.P., Faurie, F. and Grenet, N. (1990). Ammoniation of straw by urea: Extent of ureolysis and improvement of nutritive value at low level off added water. *Reprod. Nutr. Dev.*, suppl. 2: 174s.

Bocquier, F., Theriez, M. and Brelurut, A. (1987). The voluntary hay intake by ewes during the last first weeks of lactation. *Anim. Prod.*, 4: 387-394.

Castrillo, C., Fondevilla, M., Guada, J.A. and de Vega, A. (1995). Effect of ammonia treatment and carbohydrate supplementation on the intake and digestibility of barley straw diets by sheep. *Anim. Feed Sci. Technol.*, 51: 73-90.

Chenost, M., Gaillard, F. and Besle, J.M. (1991). Les cannes de maïs dans l'alimentation des ruminants. Conservation et valeur alimentaire. *Productions Animales*, 4(2): 169-175.

Chermiti, A., Nefzaoui, A. and Cordesse, R. (1989). Paramètres d'uréolyse et digestibilité de la paille traitée à l'urée. *Ann. Zootech.*, 38: 63-72.

Chesson, A., Gordon, A.H. and Lower, J.A. (1983). Substituent groups linked by alkali labile bonds to arabinose and xylose residues of legume grass and cereal straw cell walls their fate during digestion by rumen microorganisms. *J. Sci. Food Agr.*, 34: 1330-1340.

Cloete, S.W.P., de Villiers, T.T. and Kritzinger, N.M. (1983). The effect of temperature on the ammoniation of wheat straw by urea. *S. Afr. J. Anim. Sci.*, 13(3): 202-203.

Cloete, S.W.P. and Kritzinger, N.M. (1984). A laboratory assessment of various treatments conditions affecting the ammoniation of wheat straw by urea. 1. The effect of temperature, moisture level and treatment period. *S. Afr. J. Anim. Sci.*, 14(2): 55-58.

Demarquilly, C. (1979). Valeur nutritive et utilisation des sous-produits de la culture de maïs. *Bull. Tech. CRZV Theix*, 339: 411-419.

Dias-da-Silva, A.A., Mascarenhas-Ferreira, A. and Guedes, C.V.M. (1988). Effects of moisture level, treatment time and soya bean addition on the nutritive value of urea-treated maize stover. *Anim. Feed Sci. Technol.*, 19: 67-77.

Fahmy, S.T.M., Lee, N.H. and Ørskov, E.R. (1984). Digestion and utilization of straw. 2. Effect of different supplements on the digestion of ammonia-treated straw. *Anim. Prod.*, 38: 75-81.

Faverdin, P., Dulphy, J.P., Coulon, J.B., Verite, R., Garel, J.P., Rouel, J. and Marquis, B. (1991). Substitution of roughages by concentrates for dairy cows. *Livest. Prod. Sci.*, 27: 137-156.

Fernández-Rivera, S. and Kloppfenstein, T.J. (1989). Yield and quality components of corn crop residues and utilisation of these residues by grazing cattle. *J. Anim. Sci.*, 67: 597-605.

Ibrahim, M.N.M., Schiere, J.B. and Perera, H.G.D. (1986). Effect of method of urea solution application on the nutritive value of treated rice straw. *Agricultural Wastes*, 18: 225-232.

INRA (1978). *Alimentation des ruminants*, Jarrige, R. (ed.). INRA, Paris.

INRA (1988). *Alimentation des bovins, ovins et caprins*, Jarrige, R. (ed.). INRA, Paris.

Jackson, M.G. (1977). The alkali treatment of straws. *Anim. Feed Sci. Technol.*, 2: 105-130.

Joy, M., Alibés, X. and Muñoz, F. (1992). Chemical treatment of ligno-cellulosic residues whit urea. *Anim. Feed Sci. Technol.*, 38: 319-333.

Joy, M., Andueza, J.D. and Muñoz, F. (1994). Influencia de la dosis de urea y de la humedad en el tratamiento con urea en cañote de maíz. *ITEA, Vol. Extra*, 16: 33-35.

Kiangi, E.M.I., Kategile, J.A. and Sundstøl, F. (1981). Different sources of ammonia for improving the nutritive value of low quality roughage. *Anim. Feed Sci. Technol.*, 6: 377-386.

Kloppfenstein, T. (1978). Chemical treatment of crops residues. *J. Anim. Sci.*, 46(3): 841-848.

Lamb, C.S. and Eadie, J. (1979). The effect of barley supplements on the voluntary intake and digestion of low quality roughages by sheep. *J. Agric. Sci.*, 92: 235-241.

Leask, W.C. and Daynar, T.B. (1973). Dry matter yield, *in vitro* digestibility, percent protein and moisture of corn stover following grain maturity. *Can. J. Plant Sci.*, 53: 515-522.

Mandell, I.B., Christison, G.I., Nicholson, H.H. and Coxworth, E.C. (1988). The effect of variation in the water content of wheat straw before ammoniation on its nutritive value for beef cattle. *Anim. Feed Sci. Technol.*, 20: 111-124.

Mann, M.E., Cohen, R.D.H., Nicholson, H.H., Christensen, D.A. and Smart, M.E. (1988). The feeding value of ammoniate flax straw, wheat straw and wheat chaff for beef cattle. *Anim. Feed Sci. Technol.*, 21: 57-66.

Mbatya, P.B.A., Kay, M., Smart, R.I. and Kennedy, S. (1985). Methods of improving the utilization of cereal straw by ruminants. IV. The effect of intake of level of supplementation with urea and dried grass. *Anim. Feed Sci. Technol.*, 13: 281-291.

Muñoz, F., Joy, M., Faci, R. and Alibés, X. (1991). Treatment of ligno-cellulosic residues with urea. Influence of dosage, moisture, temperature and addition of ureases. *Ann. Zootech.*, 40: 215-225.

Oji, U.I. and Mowat, D.N. (1979). Nutritive value of thermo-ammoniated and steam treated maize stover. 1. Intake, digestibility and nitrogen retention. *Anim. Feed Sci. Technol.*, 4: 177-186.

Oji, U.I., Mowat, D.N. and Winch, J.E. (1977). Alkali treatment of corn stover to increase nutritive value. *J. Anim. Sci.*, 44: 79-802.

Perry, L.J. and Compton, W.A. (1977). Serial measures of dry matter accumulation and forage quality of leaves, stalks and ears of three corn hybrids. *Agron. J.*, 69(5): 751-755.

Sundstøl, F. (1988a). Straws and other fibrous by products. *Livest. Prod. Sci.*, 19: 137-158.

Sundstøl, F. (1988b). Improvement for low quality forages and roughage. In: *World animal science. B. Disciplinary approach feed science*, pp. 257-273.

Sundstøl, F. and Coxworth, E.M. (1984). Ammonia treatment. In: *Straw and other fibrous by-products as feed*, Sundstøl, F. and Owen, E. (eds). Elservier, Amsterdam-Oxford-New York-Tokyo, pp. 196-247.

Waagepetersen, J. and Vestergaard-Thomsen, K. (1977). Effect on digestibility and nitrogen content of barley straw of different ammonia treatments. *Anim. Feed Sci. Technol.*, 2: 131-142.

Wanapat, M., Chenost, M., Muñoz, F. and Kayouli, C. (1996). Methods for improving the nutritive value of fibrous feed: Treatment and supplementation. *Ann. Zootech.*, 45, suppl.: 89-103.

Williams, P.E.V., Innes, G.M. and Brewer, A. (1984a). Ammonia treatment of straw via the hydrolysis of urea. I. Effects of dry matter and urea concentrations on the rate of hydrolysis of urea. *Anim. Feed Sci. Technol.*, 11: 103-113.

Williams, P.E.V., Innes, G.M. and Brewer, A. (1984b). Ammonia treatment of straw via the hydrolysis of urea. II. Additions of soya bean (urease), sodium hydroxide and molasses; effects on the digestibility of urea-treated straw. *Anim. Feed Sci. Technol.*, 11: 115-124.

Yameogo-Bougouma, V., Cordesse, R., Arnaud, A. and Inesta, M. (1993). Identification de l'origine des uréases impliquées dans le traitement de la paille de blé dur à l'urée et caractérisation de la flore microbienne présente. *Ann. Zootech.*, 42: 39-47.