# UREA TREATMENT OF MATURE WHOLE-CROP CEREAL MIXTURES AS SALVAGE FORAGE FOR SMALL-SCALE DAIRY SYSTEMS IN THE DRY SEASON †

# [TRATAMIENTO CON UREA DE MEZCLAS DE CEREALES MADUROS COMO FORRAJE DE RECUPERACIÓN PARA SISTEMAS DE PRODUCCIÓN DE LECHE PEQUEÑA ESCALA EN LA ESTACIÓN SECA]

**Yessica Guadalupe Zamora-Juárez, Mónica Arias-Ávila, Carlos Manuel Arriaga-Jordán, Carlos Galdino Martínez-García and Felipe López-González***

*Instituto de Ciencias Agropecuarias y Rurales (ICAR), Universidad Autónoma del Estado de México (UAEM), Campus UAEM El Cerrillo, El Cerrillo Piedras Blancas, CP 50295, Toluca, Estado de México, México. Email: flopezg@uaemex.mx*
**Corresponding author*

## SUMMARY

**Background:** Forage from small-grain cereals is an option to diversify feeding strategies in small-scale dairy systems (SSDS), due to their short cycle and ample adaptation. Mixtures of cereal species may have synergic advantages; however, grazing or ensiling is not always possible due to climatic factors, so forage crops are left to mature and lose quality. Urea treatment of whole-crop mature cereal mixtures may be an option to salvage forage that could not be grazed or ensiled. **Objective:** To evaluate the performance of dairy cows fed urea-treated mature whole-crop forage mixtures of triticale (TRT), rye (RYE), and barley (BLY), in the dry season for SSDS. **Methodology**: Treatment mixtures were TRT+RYE, TRT-BLY, and RYE+BLY. Fully mature cereal mixture crops were treated with 4 - 6% granular urea (plus water) on a fresh basis. Forage variables were analysed with a split-plot design. Whole-crop forage yields were 3.4 ton/ha, with highest yields for RYE-BLY. Crude protein content increased two-fold in treated forages, and dry matter digestibility was moderate with a mean estimated ME content of 7.9 MJ ME/kg DM. Performance was evaluated by an on-farm 3x3 Latin square experimental design repeated 3 times with nine Holstein cows, experimental periods were 14 days, of which 10 days were for adaptation to feeding and 4 days for sampling. Cows were offered daily 9.0 kg DM of urea-treated forage; complemented with 4.4 kg DM of concentrate, day-grazing, and 1.5 kg of cut pasture. **Results:** There were no statistical differences (P>0.05) for any of the animal variables. Urea treatment of whole-crop mature cereal mixtures resulted in a complementary moderate quality salvage forage for the dry season. **Implications:** The present study is presented as an alternative when the crops are in a state of advanced maturation and it is intended to modify the nutritional quality of the forages. **Conclusion:** The use of urea can be an alternative to improve the nutritional quality of forages.

**Key words:** Small-scale dairy systems; small-grain whole-crop cereal mixtures; barley; rye; triticale; forage alternatives; highlands; Mexico.

## RESUMEN

**Antecedentes:** El forraje de cereales de grano pequeño es una opción para diversificar las estrategias de alimentación en los sistemas de leche en pequeña escala (SPLPE), debido a su ciclo corto y fácil adaptación. Las mezclas de especies de cereales pueden tener ventajas sinérgicas; sin embargo, el pastoreo o el ensilado no siempre es posible debido a factores climáticos, por lo que los cultivos forrajeros se dejan madurar y pierden calidad. El tratamiento con urea de las mezclas de cereales maduros de cultivos enteros puede ser una opción para recuperar el forraje que no pudo ser pastoreado o ensilado. **Objetivo:** Evaluar el desempeño de vacas lecheras alimentadas con mezclas de forraje integral maduro tratado con urea triticale (TRT), centeno (RYE) y cebada (BLY), en la estación seca para SPLPE. **Metodología**: Las mezclas de tratamiento fueron TRT+RYE, TRT-BLY y RYE+BLY. Los cultivos de mezclas de cereales totalmente maduros se trataron con 4 - 6% de urea granular (más agua) sobre una base fresca. Las variables forrajeras se analizaron con un diseño de parcelas divididas. Los rendimientos de forraje de cultivo completo fueron de 3. 4 ton/ha, con rendimientos más altos para RYE-BLY. El contenido de

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**ORCID = Felipe López-González:** http://orcid.org/0000-0002-5518-5458

proteína cruda se duplicó en los forrajes tratados y la digestibilidad de la materia seca fue moderada con un contenido medio estimado de EM de 7.9 MJ EM/kg MS. El rendimiento se evaluó mediante un diseño experimental cuadrado latino 3x3 repetido 3 veces con nueve vacas Holstein, los periodos experimentales fueron de 14 días, de los cuales 10 fueron de adaptación a la alimentación y 4 de toma de muestras. A las vacas se les ofrecieron diariamente 9.0 kg MS de forraje tratado con urea; Complementado con 4.4 kg de MS de concentrado, pastoreo diurno y 1.5 kg de pasto cortado. **Resultados:** No hubo diferencias estadísticas (P> 0,05) para ninguna de las variables animales. El tratamiento con urea de mezclas de cereales maduros de cultivo completo dio como resultado un forraje de rescate complementario de calidad moderada para la estación seca. **Implicaciones:** El presente estudio se presenta como una alternativa cuando los cultivos se encuentran en un estado de maduración avanzada y se pretende modificar la calidad nutricional de los forrajes. **Conclusión:** El uso de urea puede ser una alternativa para mejorar la calidad nutricional de los forrajes.
**Palabras clave:** Sistemas lecheros de pequeña escala; mezclas de cereales integrales de grano pequeño; cebada; centeno; triticale; alternativas forrajeras; tierras altas; México.

## INTRODUCTION

Small-scale dairy systems (SSDS) in the central highlands of Mexico are characterised by farms with limited land endowments and herds of 3 to 35 cows plus replacements, based on family labour, and with the potential to improve their productivity and sustainability (Prospero-Bernal *et al.*, 2017). One of their main limitations is high feeding costs that can represent 50-70% of total production costs requiring lower cost feeding strategies based on forages (Prospero-Bernal *et al.*, 2017).

However, a further challenge faced by SSDS are the possible effects of climate change with erratic rain seasons, longer dry spells, and lower rainfall (Ortiz-Espejel *et al.*, 2015). Therefore, the future development and sustainability of these systems require research and development of lower cost feeding strategies based on forages better adapted to the possible effects of climate change.

Small-grain cereals as forage can be an option to diversify and make more flexible feeding strategies in terms of forage production schemes for small-scale systems. One advantage is their short agronomic cycle to better cope with low rainfall, and tolerance to frost. Their potential use has been evaluated for grazing, zero-grazing, or silage, which makes them adaptable forage options in Canada (Juskiw *et al.*, 1999), Vietnam (Salgado *et al.*, 2013), Australia (Piltz *et al.*, 2021), or the highlands of central Mexico (Gómez-Miranda *et al.*, 2020; González-Alcántara *et al.*, 2020; Vega-García *et al.*, 2021).

However, agroclimatic circumstances may preclude the utilization of forages when optimal, as may be due to heavy rains that make grazing or harvesting for silage unfeasible due to waterlogged soils, leaving them to mature and complete their cycle, reducing their nutritional value for dairy cows.

One conservation option for mature forages and straws is by ammonization, which in small-scale systems may be achieved by treating forages with urea (Givens *et al.*, 1988). In addition to improving their nutritional quality by enhancing their digestibility, this treatment has the benefit of extending the harvest window (Chenost, 1996); as the possible effects of climate change prevent forages from being harvested at optimal times for other forms of utilisation as grazing or conservation such as silage, due to excess or scarce rainfall. Therefore, the preservation of very mature forages like whole-crop small-grain cereals with urea treatment represents an option to salvage mature forages for livestock feeding in the dry season, resulting in a stable forage that is less susceptible to mould.

Although in other countries there is evidence evaluating the productive potential and nutritive value of urea treated forage (Coblentz *et al.*, 2018), in Mexico there are no reports on treatment with urea of whole-crop forage of small-grain cereals.

On the other hand, there is an interest in multispecies forage crops, since evidence from multispecies pastures for dairy cows show better herbage production by achieving greater plasticity through the differences and complementarities in the growth of the different species used, which among their advantages is a lower invasion by weeds (Muciño-Álvarez *et al.*, 2021); which could also be a factor in multispecies small-grain cereal crops (Juskiw *et al.* 1999).

Among small-grain cereals with forage potential for SSDS there are: triticale, an intergeneric hybrid between wheat and rye which presents greater environmental tolerance and less nutrient loss as it matures (González-Alcántara *et al.*, 2020; Haque *et al.*, 2008; Harper *et al.*, 2017); barley, with higher digestibility and microbial protein production reducing the need for protein sources, with greater competitiveness and dominance over other species (Baron *et al.*, 2015; Gómez-Miranda *et al.*, 2020); and rye, favoured for its resistance to drought, diseases, and low temperatures (Castro *et al.*, 2011). The objective was to evaluate mature whole-crop small-grain cereal binary mixtures treated with urea. Cereals evaluated in mixtures were triticale (X. *Triticosecale* Wittmack), rye (*Secale cereale*), and barley (*Hordeum vulgare*) in feeding strategies for milking cows in small-scale dairy systems during the dry season.

## MATERIALS AND METHODS

### Study area

An on-farm experiment was carried out in the municipality of Aculco in central Mexico, located between 20° 00' and 20° 17' N and 99° 40' y 100° 00' W, and a mean altitude of 2440 m. Climate is temperate sub-humid, with a mean temperature of 13.2°C, and mean annual rainfall of 700 mm (INEGI, 2009); with frosts from October to February, and a dry season from November to April

### Crop establishment and conservation

Three binary multi-species crops of mixtures of triticale (TRT), rye (RYE) and barley (BLY) were established in plots of 1.0 ha/crop, the initial idea was to evaluate the silage, but due to weather conditions this was not possible, so the alternative was to enrich it with non-protein nitrogen. The binary crops were TRT-RYE, TRT-BLY, and RYE-BLY. A ternary crop (TRT-RYE-BLY) was also sown but did not conserved properly so that was not included in the evaluation.

Crops were sown on 18 May 2021 at a seeding rate of 50 kg per species in the binary crops for a total rate of 100 kg cereal seed/ha and fertilised with 90N-80P-90K kg/ha (150 kg urea /ha, 175 kg diammonium phosphate/ha, and 150 kg potassium chloride/ha). The whole-crop cereal mixtures were harvested on 13 November 2021 (247 days after sowing) at a height of 5 cm from the ground with a flail chopper forage harvester at full maturity.

Each forage crop was treated with between 4 and 6 % urea on a fresh weight basis. The forages were treated with the following urea percentages: TRT + RYE at 5.28 %, for TRT + BLY 4.95 % and RYE + BLY 4.53 %. The chopped forage was placed in layers over a black plastic sheet, slightly compacted with a tractor and 50 kg of granulated urea applied per harvested layer, and each layer was sprinkled with water to increase moisture and facilitate the hydrolysis of urea (a total of 450 litres of water per crop). Finally, the forage silos were wrapped with a black plastic sheet and the flaps sealed with soil to prevent the escape of ammonia gas produced by ureolysis. Cake silos were made, covered with plastic and remained covered for 28 days, the pH of the forages once they were uncovered was 6.8 on average.

However, the three-species silo had mould growth, ruling it out for consumption by the dairy cows so only the three binary crop treatments were used.

### Animals and treatments

The three binary multi-species urea-treated small-grain cereal crops were evaluated as the following treatments TRT+RYE, TRT+BLY, and RYE+BLY.

Nine Holstein cows with mean live weight of 455 ± 4.47 kg, body condition score (BCS) of 2.2 ± 0.04, mean daily milk yield of 12.4 ± 0.88 kg/cow, and 159 ± 5.18 days in milk on average were used; arranged in three groups of three similar cows each for higher yielders, intermediate yielders, and low yielders. A 3 x 3 Latin Square experimental design replicated three times was used, allocating at random treatments per square and cows to treatment sequences.

Experimental diets were 9.0 kg DM of urea-treated binary cereal forage; complemented with 4.4 kg DM of a commercial dairy concentrate with 18% crude protein (divided in two meals offered at milking), day-grazing for 6 h/day between milkings in 3.0 ha of Kikuyu grass (*Cenchrus clandestinus*) - white clover (*Trifolium* repens) pasture with minimal growth over the experiment and grazed both by the experimental cows and other lactating dairy cows (16 cows in total) plus four non-lactating heifers equivalent to a stocking rate of 6.8 dairy cows/ha.

The collaborating farmer insisting on providing 1.5 kg DM/cow/day of cut mature Kikuyu grass; which although deemed not necessary, one of the premises of participatory rural research by on-farm experiments is to respect the interests and decisions of collaborating farmers (Conroy, 2005).

Cows were machined milked at 7:00 and 17:00 h and kept overnight in a concrete floor pen.

### Chemical composition of milk and feeds

Milk samples were taken at milking from each cow to determine chemical composition using an ultrasound milk analyser. A second sample was taken to determine milk urea nitrogen (MUN) concentration by the enzymatic colorimetric method as reported by Chaney and Marbach (1962).

The chemical analysis of forage samples to determine DM, OM, CP, NDF, ADF, IVDMD and ME variables, followed established procedures described in previous works (Celis-Alvarez *et al.* 2017).

The intake of the cows was determined through the metabolisable energy used by the animal, considering the weight of each cow (2.8 % of the animal's weight), considering the needs of maintenance, lactation and gestation. maintenance, lactation and gestation needs, from the sum of this is subtracted the concentration of metabolisable concentration of metabolisable energy provided by the commercial concentrate and the inclusion of urea-treated fodder and the rest is provided by the pasture (Hernandez-Mendo and Leaver, 2006).

**Experimental design and statistical analysis**

Animal variables were analysed as a 3x3 Latin square experimental design repeated three times with double randomisation, with three treatments and three experimental periods of 14 days each, according to the following model (Kaps and Lamberson, 2004. The experimental periods were in accordance with Miguel et al, (2014), who mention that the periods can be short if there are no drastic changes in feeding.

$Yjkl = \mu + Si + C(i)j + Pk + t_l + ejkl$

Where: Yjkl = Response variable; μ= Overall mean; S=Effect of squares ($\boldsymbol{i}$ = A, B, C); C= Effect of cows within squares (j = 1, 2, 3); P= Effect of experimental periods (k = 1, 2, 3); t= Effect of treatments (l=TRT+RYE, TRT+BLY, RYE+BLY); e= Residual variation.

Forage production variables were analysed with a split-plot design, where the main plots (MP) were the treatments, and the split plots (sp) were experimental periods following Vega-García *et al.* (2021). The results were analysed using an analysis of variance with the following model (Kaps and Lamberson, 2004):

$Yijkl = \mu + sdi + Tj + Ek + pl + Tpjl + Trjm + eijk.$

Where: Yjkl = Response variable; μ= Overall mean; sd= Effect of subdivision in crops ($\boldsymbol{i}$ = 1, 2, 3); T= Effect of Treatments (Main Plots) (j = TRCN, CBCN, TRCB); E= Residual term for Main Plots; p= Effect of experimental periods (Split Plots) (l= 1, 2, 3); Tp= Effect of the interaction between treatments and experimental period; Tr= Effect of the interaction between treatments and replicates within each crop subdivision; e= Residual term for Split Plots.

Tukey's test was applied if significant differences were detected.

## RESULTS

**Forage production**

Forage yields at harvest of whole-crop fully mature binary mixtures of cereals and final concentration of urea at treatment time were 2.8 ton DM/ha for TRT+RYE treated with 5.28% urea, 3.0 ton DM/ha and 4.95% urea for TRT+BLY, and 4.4 ton DM/ha for RYE+BLY and 4.53% urea.

Th Kikuyu grass grazed pasture (KY) had a mean net herbage accumulation of 593.2 kg DM/ha per period, representing 42.4 kg DM/ha/day providing an availability of 3.0 kg DM/cow equivalent/day.

**Chemical composition of forages**

The chemical composition results of the binary cereal mixtures before treatment are shown in Table 1, and Table 2 shows the chemical composition of forages treated with urea.

Results for pre-treatment fully mature cereal mixtures indicated low crude protein content, high neutral and acid detergent fibre contents, with a moderate digestibility (mean 526 g/kg DM) and estimated ME content (7.4 MJ ME/kg DM), higher than straws due mainly from the grain content in spikes as a whole-crop.

Treated small-grain cereal mixtures had an over two-fold increase in crude protein content due to the urea treatment increasing from a mean of 59.3 g CP/kg DM to 132.4 g CP/kg DM in the treated forages.

Both NDF and ADF contents increased in treated forages, and there was a modest 6-7% increase in IVDMD and ME content compared to pre-treatment values.

**Table 1. Pre-treatment chemical composition of binary mixtures of small-grain whole-crop cereals (g/kg DM).**

| Variable | Treatment | | | Mean | SEM | P-Value |
|---|---|---|---|---|---|---|
| | TRT-RYE | TRT-BLY | RYE-BLY | | | |
| DM | 29.7[a] | 27.2[b] | 30.4[a] | 29.1 | 1.6 | 0.033* |
| OM | 940.4 | 931.2 | 940.2 | 937.3 | 5.3 | 0.384[NS] |
| CP | 63.6 | 58.6 | 55.7 | 59.3 | 4.0 | 0.693[NS] |
| NDF | 692.9[a] | 659.5[b] | 698.7[a] | 683.7 | 21.2 | 0.011* |
| ADF | 450.6[a] | 391.4[b] | 441.6[a] | 427.9 | 31.9 | 0.015* |
| IVDMD | 462.7 | 574.9 | 540.8 | 526.1 | 57.5 | 0.132[NS] |
| EM (MJ/kg) | 6.3 | 8.2 | 7.6 | 7.4 | 1.0 | 0.135[NS] |

TRT= Triticale; BLY= Barley; RYE= Rye; DM= Dry matter; OM= Organic matter; CP= Crude protein; NDF= Neutral Detergent Fibre; ADF= Acid Detergent Fibre; IVDMD= In vitro dry matter digestibility; ME= Metabolizable energy; SEM = Standard Error of the Mean; NS= P>0.05; *= P<0.05; a,b= P<0.05.

**Table *2*. Chemical composition of binary small-grain cereal crops treated with urea (g/kg DM).**

| Variable | Period | Treatment | | | Mean Period | SEM sp | P MP | P sp | P MP*sp |
|---|---|---|---|---|---|---|---|---|---|
| | | TRT+RYE | TRT+BLY | RYE+BLY | | | | | |
| DM (g/kg DM) | I | 922.9 | 874.3 | 790.9 | 862.7 | 10.7 NS | 0.182 | 0.933 | 0.892 |
| | II | 938.8 | 917.9 | 759 | 871.9 | | | | |
| | III | 931.5 | 797 | 809.3 | 845.9 | | | | |
| Mean Tx | | 931 | 863.1 | 786.4 | | | | | |
| SEM MP | | | 59.1 NS | | | | | | |
| SEM MP*sp | | | 12.1 NS | | | | | | |
| OM (g/kg DM) | I | 926.7 | 922.3 | 916.7 | 921.9 | 5 NS | 0.732 | 0.58 | 0.996 |
| | II | 919.3 | 919.2 | 911.1 | 916.5 | | | | |
| | III | 908.7 | 915.8 | 904.3 | 909.6 | | | | |
| Mean Tx | | 918.2 | 919.1 | 910.7 | | | | | |
| SEM MP | | | 3.8 NS | | | | | | |
| SEM MP*sp | | | 0.8 NS | | | | | | |
| CP (g/kg DM) | I | 101.9 | 184.3 | 128.2 | 138.2 | 6.8 NS | 0.002 | 0.213 | 0.052 |
| | II | 118.2 | 165.3 | 124.7 | 136.1 | | | | |
| | III | 120.9 | 125.1 | 122.5 | 122.9 | | | | |
| Mean Tx | | 113.7[b] | 158.3[a] | 125.1[b] | | | | | |
| SEM MP | | | 18.9* | | | | | | |
| SEM MP*sp | | | 5.5 NS | | | | | | |
| NDF (g/kg DM) | I | 826 | 718.1 | 804.4 | 782.9[a] | 40.1* | 0.156 | 0.049 | 0.661 |
| | II | 776.7 | 685.1 | 746.7 | 736.2[a] | | | | |
| | III | 670.7 | 677.7 | 705.5 | 684.7[b] | | | | |
| Mean Tx | | 757.8 | 693.6 | 752.3 | | | | | |
| SEM MP | | | 29 NS | | | | | | |
| SEM MP*sp | | | 8.6 NS | | | | | | |
| ADF (g/kg DM) | I | 549.4 | 473.7 | 554 | 525.7 | 23.3 NS | 0.014 | 0.15 | 0.931 |
| | II | 567.9 | 450.3 | 536.9 | 518.4 | | | | |
| | III | 492.5 | 419 | 507.5 | 473 | | | | |
| Mean Tx | | 536.6[a] | 447.6[b] | 532.8[a] | | | | | |
| SEM MP | | | 41.1* | | | | | | |
| SEM MP*sp | | | 3.9 NS | | | | | | |
| IVDMD (g/kg DM) | I | 479.1 | 625.3 | 531.9 | 545.4 | 27.9 NS | 0.191 | 0.266 | 0.334 |
| | II | 558.5 | 560.6 | 480.8 | 533.3 | | | | |
| | III | 650.1 | 601.1 | 541.3 | 597.5 | | | | |
| Mean Tx | | 562.6 | 595.7 | 518.0 | | | | | |
| SEM MP | | | 31.8 NS | | | | | | |
| SEM MP*sp | | | 14.9 NS | | | | | | |
| ME (g/kg DM) | I | 7 | 9.1 | 7.4 | 7.8 | 0.5 NS | 0.187 | 0.294 | 0.47 |
| | II | 7.9 | 7.9 | 6.6 | 7.5 | | | | |
| | III | 9.5 | 8.6 | 7.6 | 8.6 | | | | |
| Mean Tx | | 8.1 | 8.5 | 7.2 | | | | | |
| SEM MP | | | 0.6 NS | | | | | | |
| SEM MP*sp | | | 0.2 NS | | | | | | |

TRT= Triticale; BLY= Barley; RYE= Rye; DM= Dry matter; OM= Organic matter; CP= Crude protein; NDF= Neutral Detergent Fibre; ADF= Acid Detergent Fibre; IVDMD= *In vitro* dry matter digestibility; ME= Metabolizable energy; SEM MP= Standard Error of the mean of Main Plots; SEM sp= Standard Error of the mean of split plots; SEM MP*sp= Standard Error of the mean of the interaction of Main Plots and split plots; P MP= P value of Main Plots; P sp= P value of split plots; P MP*sp= P value of the interaction of Main Plots and split plots; NS= P>0.05; *= P<0.05,[a,b].

**Feed supplements**

The results of the chemical composition of the Kikuyu grass grazed pasture (KY) and the cut pasture fed indoors (PS) are shown in Table 3.

Grazed KY was of high nutritional quality with a high CP content, IVDMD of 776 g/kg DM, and an estimated ME content of 11.6 MJME/kg DM. The PS cut pasture, in spite of being mature and with a low CP content and high fibre content, had a moderately high IVDMD of 660 g/kg DM which represented an estimated ME content of 9.6 MJME/kg DM.

**Animal variables**

Animal production results are shown in Table 4. Milk yield expressed as 3.5 Fat-corrected milk was moderate (13.7 kg/cow/day) with small cows with a mean live weight of 461 kg. Fat content in milk was high compared to reports in these systems (Prospero-Bernal *et al.*, 2017), with milk urea nitrogen within normal ranges.

Refusals of treated forages were high, representing over 20% of offered forage, reflecting the effect of the complementary grazing and cut pasture offered.

## DISCUSSION

**Yield and chemical composition of forages**

In spite of being fully mature, the forage yield of the binary mixtures of small-grain cereals was similar to reports by González-Alcántara *et al.* (2020) for triticale silage and similar to the yield of rye with 3.5 and triticale with 4.3 ton DM/ha reported by Vega-García *et al.* (2023).

The pre-experimental results of chemical composition of the multi-species small-grain cereal crops were very similar to each other, where of OM, CP, IVDMD and ME contents were not statistically different among them (P>0.05).

The pre-experimental results of chemical composition of the multi-species small-grain cereal crops treated with urea are very similar to each other, according to the variables of OM, CP, IVDMD and ME, where no statistically significant differences were observed (P>0.05). Although it is worth mentioning that, in the last two variables, it could be considered that there was a numerically significant difference between treatments; because the treatments containing BLY seem to have a higher IVDMD compared to the one without and it could be because this small-grain cereal has a layer with a high level of ß-glucans and starch granules, which favours its digestibility (Newton *et al.*, 2011) so it is commonly used in dairy cattle diets because it optimises rumen microbial performances (Baron *et al.*, 2015); while the difference in ME between treatments is 1 to 2 MJ/kg which could translate into a difference of up to 20g/kg protein and 15 g/kg fat depending on weight and breed, according to Moran (2005), but they meet the energy needs of the cows to produce the amount of fat and protein reported in Table 4, because the selected cows were of the same breed and similar yields.

The treated forages met the nutrient requirements of the cows to produce the moderate milk yields, as well as the fat and protein reported in Table 4.

**Table 3. Chemical composition of grazed and cut pastures.**

| Variable | CC | Period I | Period II | Period III | Mean | SEM | P |
|---|---|---|---|---|---|---|---|
| | | | | KY | | | |
| DM (g/kg DM) | 90.0 | 352.4 | 377.1 | 375.1 | 368.2 | 15.5[NS] | 0.639 |
| OM (g/kg DM) | - | 888.2 | 893.3 | 882.8 | 888.1 | 0.5 [NS] | 0.003 |
| CP (g/kg DM) | 176.5 | 187.3 | 194.3 | 187.4 | 189.6 | 4.9 [NS] | 0.676 |
| NDF (g/kg DM) | 295.5 | 577.9 | 533.7 | 551.1 | 554.2 | 9.7[NS] | 0.164 |
| ADF (g/kg DM) | 85.4 | 247.7 | 235.1 | 245.2 | 242.7 | 3.3[NS] | 0.215 |
| IVDMD (g/kg DM) | 915.3 | 746.4 | 790[b] | 791.5[a] | 775.9 | 5.9* | 0.035 |
| ME (MJ/kg DM) | 13.4 | 11.1[b] | 11.9[a] | 11.9[a] | 11.6 | 0.1* | 0.034 |
| | | | | PS | | | |
| DM (g/kg DM) | - | 796.1[a] | 562.5[c] | 604.3[b] | 654.3 | 0.6* | 0 |
| OM (g/kg DM) | - | 891.8 | 888.9 | 884.2 | 888.3 | 1.2[NS] | 0.078 |
| CP (g/kg DM) | - | 77.1 | 73.5 | 84.0 | 78.2 | 4[NS] | 0.418 |
| NDF (g/kg DM) | - | 664.8[a] | 665.1[a] | 634.5[b] | 654.8 | 1.01* | 0.001 |
| ADF (g/kg DM) | - | 312.6 | 327.8 | 322.9 | 321.1 | 2.5[NS] | 0.079 |
| IVDMD (g/kg DM) | - | 621.2 | 675.9 | 683.1 | 660.0 | 12.5[NS] | 0.114 |
| ME (g/kg DM) | - | 9.0 | 9.9 | 10.1 | 9.6 | 0.22 [NS] | 0.112 |

KY= Kikuyu grass grazed pasture; PS= Cut pasture; DM= Dry matter; OM= Organic matter; CP= Crude protein; NDF= Neutral Detergent Fibre; ADF= Acid Detergent Fibre; IVDMD= *In vitro* dry matter digestibility; ME= Metabolizable energy; NS= P>0.05; *= P<0.05,[abc].

**Table 4. Performance of Holstein cows fed binary small-grain cereal crops treated with urea.**

| Variable | Treatment | Period | Mean | SEM | P Tx | P EP | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | TRT+RYE | TRT+BLY | RYE+BLY | I | II | III | | | | |
| MY | 12.4 | 12.8 | 12.5 | 12.5 | 12.3 | 12.4 | 12.4 | 0.41 | 0.699 | |
| FCM (kg/cow/day) | 14.5 | 13.1 | 13.6 | 14.2 | 13.1 | 13.8 | 13.7 | 0.78 $^{NS}$ | 0.122 | 0.24 |
| Milk fat (g/kg) | 48.0 | 40.0 | 44.0 | 45.7 | 39.3 | 46.8 | 43.9 | 3.68 $^{NS}$ | 0.059 | 0.053 |
| Protein (g/kg) | 27.2 | 29.1 | 27.1 | 29.4b | 31.1a | 22.9c | 27.8 | 1.19 $^{*}$ | 0.101 | 0.05 |
| SNG (g/kg) | 74.2 | 79.6 | 74.4 | 80.4$^{a}$ | 85.1$^{a}$ | 72.8$^{b}$ | 79.4 | 2.25 | 0.101 | 0.000 |
| MUN (mg/dL) | 16.5 | 15.6 | 15.3 | 17.8a | 15.9b | 13.6c | 15.8 | 1.81 $^{*}$ | 0.691 | 0.042 |
| LW (kg) | 462.2 | 452.7 | 469.8 | 458.8 | 461.3 | 464.6 | 461.6 | 10.2 $^{NS}$ | 0.156 | 0.791 |
| RTF kg/day) | 2.2 | 1.9 | 2.1 | 2.8$^{a}$ | 2.3$^{b}$ | 1.1$^{c}$ | 2.1 | 0.47 $^{*}$ | 0.728 | 0.002 |
| BCS (1-5) | 2.3 | 2.2 | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 0.08 $^{NS}$ | 0.272 | 0.242 |
| DMI | 13.9 | 13.8 | 13.5 | 13.6 | 13.7 | 13.8 | 13.7 | 0.84 | 0.152 | 0.236 |

MY= Milk yield; FCM= Fat-corrected 3.5%; MUN= Milk urea nitrogen; LW= Live weight; RTF= Refusals of urea treated forages; BCS= Body condition score; TRT= Triticale; BLY= Barley; RYE= Rye; DMI= dry matter intake; SEM= Standard Error of the Mean; P Tx= P value for Treatments; P EP= P value for Experimental Periods; NS= P>0.05; *= P<0.05; $^{a,b}$.

On the other hand, the variables that did show statistically significant differences (P<0.05); DM, NDF and ADF; can be explained by the characteristics of each small-grain cereal. The DM reported in treatments containing RYE were higher probably because of the good performance of rye previously reported by other authors (Celis-Álvarez *et al.*, 2017; Coblentz *et al.*, 2018); and the fibre results, dependent on the phenological stage of the small-grain cereal, were also higher in the treatments containing RYE due to its morphology as it has a higher stem proportion that is reflected in a greater content of cellulose, hemicellulose and lignin (Baron *et al.*, 2015). Given the full maturity of whole-crop forages herein reported, fibre contents are higher than those reported by Gómez-Miranda *et al.* (2020; 2022) and Vega-García *et al.* (2021) who evaluated small-grain cereal forages at an earlier phenological stage.

The results of the mature whole-crop cereal mixtures treated with urea showed there were no statistically significant differences (P>0.05) for DM, OM, IVDMD and ME contents; where urea treated forages had higher digestibility and ME content than the pre-experimental untreated crops.

As for the rest of the variables, statistically significant differences (P<0.05) were found among treatments for CP and ADF; and between periods for NDF. The treatment with the highest CP was that of TRT+BLY, which improved considerably compared to pre-experimental values; and the lowest increase in CP was that of TRT+RYE.

Results confirmed reports from several authors in different regions (Castejon and Leaver, 1994; Chenost, 1996; Deschard *et al.*, 1987; García-Martínez *et al.* 2020; Kiangi *et al.*, 1981) that showed how the urea treatment of low quality forages improved their nutritional value due to the effect of ammonia released from the urea on the cellulose and hemicellulose even at a late stage of maturation.

DM, OM and NDF variables are by far, different from the results reported for BLY silage by Gomez-Miranda *et al.* (2020) with 226.0 g/kg DM, 788 g/kg

DM and 568 g/kg DM, respectively, although for CP (66 g/kg DM) and ADF (420 g/kg DM) the results were similar.

Results shown in Table 2 compare and are similar to the OM of RYE (934 g/kg DM) and TRT (926 g/kg DM) reported by Vega-García *et al.* (2021); the NDF (698 g/kg DM) content of maize straw treated with urea reported by Oji *et al.* (2007); the IVDMD (571 g/kg DM) of maize straw treated with urea reported by García-Martínez *et al.* (2020); and an ME content of 7.3 MJ EM/kg DM of wheat straw treated with urea reported by Kashongwe *et al.* (2014).

The results of DM, NDF and ADF of maize straw treated with urea from García-Martínez *et al.* (2009; 2020) (927 and 900 g/kg DM; 710 and 721 g/kg DM; 523 and 486 g/kg DM) and of maize stalks also treated with urea reported by Oji *et al.* (2007) (850 g/kg DM; 698 g/kg DM; 505 g/kg DM) are similar to those found in this study.

The OM (926, 934 and 929 g/kg DM) and CP (150, 136 and 135 g/kg DM) contents of the triticale and rye crops reported by Vega-García *et al.* (2021) and the 59 cm barley crop reported by Gómez-Miranda *et al.* (2022), respectively, were also similar to the small-grain whole-crop cereal mixtures treated with urea reported in Table 4.

On the other hand, the IVDMD and ME contents reported by García-Martínez *et al.* (2020) for maize straw treated with urea were similar results to the forages treated with urea of this work (571 g/kg DM and 9.2 MJ/kg), despite the fact that García-Martínez *et al.* (2020) worked with maize straw and not small-grain cereals.

**Complementary pastures**

Results from the KY grazed pasture were similar only in the OM and CP contents with 888 and 182 g/kg DM, respectively to those reported by Plata-Reyes *et al.* (2021); while Marín-Santana *et al.* (2020) showed differences in all the variables of chemical composition of the KY pasture in that experiment.

The cut pasture (PS) only presented similarities in OM and ADF content with 872 and 310 g/kg DM, respectively, compared to what reported by Gómez-Miranda *et al.* (2020) in the third period of their experiment in the rainy season. Resutls for the commercial concentrate were in accordance with the label statement.

Therefore, mature whole-crop cereal mixtures treated with urea did improve forage quality despite its advanced phenological stage, especially those containing triticale.

**Supplements**

The KY pasture and the cut pasture (PS) did not show differences between periods (P>0.05), and the chemical composition of the concentrate was as stated in the label, so the feed supplements kept the same chemical during the experiment without representing an effect in the dairy cows' diet; but the estimated ME content of the supplements was much higher than that of the treated with urea.

**Animal production**

Milk yields during the experiment were higher than pre-experimental yields and did not show differences among experimental periods (P>0.05), which without differences in liveweight and body condition score (P>0.05), indicated that the urea treated forages and supplements provided an improved and stable feeding in these systems during the dry season.

The mean of 20% refused treatment forages may have been due to the supplements that complemented the diet of experimental cows (concentrate, grazing, and cut pasture). Urea treated forages may be rejected by cattle as it may be considered pungent due to ammonia accumulation and not very palatable especially at the beginning when the forage is just uncovered from the plastic covering (Deschard *et al.*, 1987).

However, refusals of treated forages significantly decreased during the experiment, from 2.8 kg DM/cow/day in Period I, to 1.1 kg DM/cow/day in Period III, indicating adaptation of the cows to the treated forages, as well as a reduced reliance on the supplementary grazed and cut pasture. In any case, urea treated whole-crop small-grain cereal mixtures represented almost 50% of the estimated DM intake.

Regarding milk composition, mean fat yield (44 g/kg) was considerably higher than what is established in Mexican standards for raw milk (≥ 32 g/L), with a statistical trend (P=0.06) for higher milk fat content in TRT+RYE.

Milk protein content was slightly below the minimal content established in Mexican standards for raw milk. The content of milk components at a given time are affected by season, days in milk, pregnancy and genetic factors, so it is a complex process where there may be trade-offs between components (Moro *et al.*, 2016). Jenkins and McGuire (2006) mentioned that the depression of proteins in milk may be an indirect effect of lower energy intakes in diets with a high forage proportion.

Results from Table 4 are similar to those reported by Vega-García *et al.* (2021) from cows grazing small-grain cereals in the rainy season in milk yields with a mean of 13. 4 kg/cow/day, milk protein with 28.2 g/kg TRT), MUN (16.1 mg/dlL) and LW (469 kg /cow).

Regarding milk fat results, Sinclair *et al.* (2007) reported 39.9 g/kg milk for dairy cows fed urea-treated whole-crop wheat, similar to the milk fat content for experimental cows fed fully mature forage from binary mixtures of cereals treated with urea in the experiment herein reported.

Jonker *et al.*, (2002) mentioned that MUN content indicates the nutritional status of dairy cows in terms of protein and energy balance, useful to evaluate diets and identify if it is necessary to modify the nutrients in the diet, as they are reflected in urinary N excretion which is directly related to milk excretion (Depeters and Ferguson *et al.*, 1992), and in turn allows to avoid unnecessary emissions of N to the environment, thus reducing costs feeding costs and the environmental footprint. Powell et al, (2011), mention that the normal values of urea nitrogen in milk for Hostein cows range between 11 and 18 mg/dL, the results of this work are within the ranges mentioned by these authors.

Milk urea contents were within normal values and was not different among treatments (P>0.05), but significantly decreased (P<0.05) as the experiment progressed, from 17.8 mg/dL in Period I to 13.6 mg/dL in Period III (Table 4).

The observed MUN values were higher than levels reported by Vega-García *et al.* (2021) in cows grazing rye and triticale pastures, which report up to 16.1 mg/dL, respectively, in contrast to Gómez-Miranda *et al.* (2022), who reported values no higher than 12 mg/dL for cows grazing barley.

## CONCLUSION

The treatment with urea of whole-crop mature small-grain cereal mixtures resulted in a viable complementary moderate quality salvage forage for feeding moderate yielding dairy cows in small-scale dairy systems during the dry season.

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**Conflicts of interest.** The authors declare that they have no conflict of interest.

**Compliance with ethical standards.** Experimental procedures with dairy cows and work with the collaborating farmer followed guidelines accepted by *Instituto de Ciencias Agropecuarias y Rurales* (ICAR) of *Universidad Autónoma del Estado de México*.

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