CHILEAN JOURNAL of AGRICULTURAL RESEARCH

CHILEANJAR
CHILEAN JOURNAL of AGRICULTURAL RESEARCH

RESEARCH ARTICLE

# Wheat or maize silage in feeding strategies for cows in small-scale dairy systems during the dry season

**Cloe D. Álvarez-García[1], Carlos M. Arriaga-Jordán[1], Julieta G. Estrada-Flores[1], and Felipe López-González[1*]**

[1]Universidad Autónoma del Estado de México, Instituto de Ciencias Agropecuarias y Rurales (ICAR), Campus UAEM El Cerrillo, CP 50090, Toluca, Estado de México, México.
[*]Corresponding author (flopezg@uaemex.mx).
Received: 25 November 2022; Accepted: 23 January 2023, doi:10.4067/S0718-58392023000400398

## ABSTRACT

The conservation of forage as silage allows its application during the dry season in dairy cattle feeding. The most commonly used forage for this purpose is maize (*Zea mays* L.), but due to the possible effects of climate change, the diversification of crops with shorter agronomic cycles as wheat (*Triticum aestivum* L.) should be considered. Therefore, the objective was to evaluate the chemical composition of silages, the productive response of dairy cows fed wheat and maize silage, as well as their feeding costs. Three treatments were evaluated with 9.8 kg DM cow$^{-1}$ d$^{-1}$ silage plus 4.6 kg DM cow$^{-1}$ d$^{-1}$ commercial concentrate each. Treatments were 100% wheat silage (WS), 50% wheat silage-50% maize silage (WMS), and 100% maize silage (MS). Six Holstein cows were used in groups of three randomly assigned to treatment sequence in a 3×3 Latin square design repeated twice. There were significant differences ($P < 0.05$) between treatments in silage chemical composition, except in NDF and ADF ($P > 0.05$). There were nonsignificant differences in animal variables ($P > 0.05$) with mean milk yield of 15.4 kg cow$^{-1}$ d$^{-1}$, 33.7 g kg$^{-1}$ milkfat, 30.5 g kg$^{-1}$ milk protein, 481.2 kg live weight and 2.1 body condition score. There were significant differences ($P < 0.05$) in silage and total DM intake in the third experimental period (three periods, 14 d each one) with 8.1 and 12.7 kg DM cow$^{-1}$ d$^{-1}$, respectively. Although cost for wheat silage were higher than maize silage, all three treatments showed positive margins on feeding costs.

**Key words:** Dairy production systems, dry season, silage, wheat.

## INTRODUCTION

It is estimated that around 150 million small-scale dairy farms are engaged in milk production worldwide, most of them in developing countries, so if properly managed, the small-scale dairy sector could serve for poverty reduction (Hemme and Otte, 2010). In Mexico, small-scale milk production systems are characterized by herds of 3 to 35 cows plus replacements, comprised over 70% of specialized dairy farms and accounted for over a third of national milk production (Martínez-García et al., 2015). Within these systems, dairy farmers face uncertainty factors, such as the price of inputs and products (Posadas-Domínguez et al., 2013), which is related to feed costs, as these range from 52% to 70% of production costs (Martínez-García et al., 2015) in addition to a high dependence on external inputs such as commercial concentrate, straw, and hay, which limits their sustainability (Gómez-Miranda et al., 2020a).

The importance of ruminants lies in their ability to convert forage into food of animal origin, which becomes more relevant in terms of global food production as the population grows in the coming decades (Wilkinson and Davies, 2012), e.g., globally milk production is projected to grow by 1.8% in the next decade (OECD-FAO, 2022).

On the other hand, the growth of agricultural crops depends on climatic conditions, as the greatest amount of green forage is produced when there is greater availability of water (OECD-FAO, 2022), subsequently there will be limitation in the growth of forage, linked to the scarcity of rainfall (Martínez-Fernández et al., 2014).

Among forage crops, maize (*Zea mays* L.) is the crop most used by small-scale farmers, mostly as silage because of its high concentration of soluble carbohydrates that allow good fermentation (Albarrán et al., 2012). However, due to the possible effects of climate change, diversification of crops used for animal feed should be considered, with shorter agronomic cycles, such as small grain cereals (Becerril-Gil et al., 2018), which require less water compared to maize, with good yields and nutritional quality, which can adapt to adverse climatic situations (Vega-García et al., 2020). Among these cereals is wheat (*Triticum* spp.), which is the most cultivated cereal in the world (Vega-García et al., 2021) that has a wide range of adaptation, grows in diverse environments, and can be sown in both spring and winter (Hernández et al., 2015).

Forage conservation as silage is a source of nutrients for livestock nutrition in many countries (Wilkinson and Davies, 2012). The importance of this lies in taking advantage of the excess forage produced during the rainy season (Martínez-Fernández et al., 2014), for use during the dry season (Vega-García et al., 2021). Silage is defined as a process of preserving forage in a wet state by acidification through fermentation, which prevents plant decay and undesirable microbial activity (Martínez-Fernández et al., 2014).

The use of silage makes it possible to maintain the body condition of the animals during the dry season without reducing production efficiency (Velázquez-Martínez et al., 2022). Therefore, the hypothesis is that whole-crop wheat preserved as silage is a forage option for feeding dairy cows during the dry season, with which, the objective was to evaluate the chemical composition, in vitro digestibility, and productive response with the use of wheat silage, wheat silage with maize and maize in the feeding of dairy cows in small-scale dairy systems.

## MATERIALS AND METHODS

### Study area

An on-farm experiment was undertaken with a participating farmer, following a rural participatory research approach (Conroy, 2005); since, according to Stroup et al. (1993) for developing countries to meet food demand, farmers must become active participants in the development process and in agricultural research. The participating farmer was informed of the objectives and the experiment followed his management decisions; and his and his family’s privacy was respected, so names are not included.

The procedures were carried out according to the guidelines of Instituto de Ciencias Agropecuarias y Rurales (ICAR) of Universidad Autónoma del Estado de México and the experiment was institutionally approved (11-MAY-2022-01).

The experiment was conducted in the municipality of Aculco (20°06′-20°17′ N, 99°40′-100°00′ W; 2440 m a.s.l.), located in the northwest the State of Mexico, with a sub-humid temperate climate and annual rainfall of 700 to 1000 mm (López-González et al., 2017). The experiment was carried out during the dry season and lasted 42 d divided into three periods of 14 d each, with 11 d of adaptation to the diet and 3 d of sampling and measurements, which began on 18 January 2022 and ended on 11 March 2022.

### Crop management and crop variables

Maize (*Zea mays* L.) crop was sown according to the practices of the participating farmer on 23 May 2021, with 30 kg ha$^{-1}$ seed and fertilized with 138 kg ha$^{-1}$ N, harvested on 1 November 2021 at 161 d post sowing in a milk-dough stage. The wheat (*Triticum aestivum* L.) crop was sown on 26 August 2021 with a sowing density of 120 kg ha$^{-1}$ seed, with a fertilizer rate of 103 N-60 P-40 K kg ha$^{-1}$, divided into two applications, at sowing and 25 d after sowing. The crop was harvested on 3 December 2021, 99 d after sowing, at a milk-dough stage. Both crops were harvested and then ensiled separately in a ground silo. The harvested forage was compacted with a tractor and covered with a sheet black plastic (600-calibre) and sealed with soil on top.

Herbage mass was estimated cutting to 10 cm ground level forage samples with a 0.5 × 0.5 m metal square placed at random. Forage samples were dried in a draught oven at 55 °C for 48 h, results were reported in kg DM $ha^{-1}$. Forage height was recorded in m with a measuring tape.

## Animals and treatments

The experiment was conducted with six Holstein cows in first and second third of lactation, with a similar milk daily yield and mean live weight of 482 ± 87 kg $cow^{-1}$. Cows were grouped according to number of calvings and pre-experimental milk yield, where each pair of cows was assigned a treatment under a 3×3 Latin square experimental design repeated twice. Three treatments were evaluated: 100% Maize silage (9.8 kg DM $cow^{-1}$ $d^{-1}$) (MS), 50% maize silage (4.9 kg DM $cow^{-1}$ $d^{-1}$)/50% wheat silage (4.9 kg DM $cow^{-1}$ $d^{-1}$) (WMS) and 100% wheat silage (9.8 kg DM $cow^{-1}$ $d^{-1}$) (WS). The cows also received 4.6 kg DM $cow^{-1}$ $d^{-1}$ commercial concentrate and free access to water in the pen.

## Animal variables

The milk yield of each cow was recorded in kg $cow^{-1}$ $d^{-1}$ during the last 3 d of each experimental period with a clock scale (Torino-Oken, Mexico). Milking was carried out with a milking machine (model TJAL-252-G, Ordemex, Mexico) twice a day (05:00 and 16:00 h). Milk samples were taken to form 100 mL aliquots, for this purpose, samples were taken from each cow during the morning and afternoon milkings, which were mixed in equal proportions to later determine the chemical composition of the milk.

Live weight (LW) was recorded on two consecutive days with an electronic scale (model W310, Gallagher, Hamilton, New Zealand) and body condition score (BCS) was measured on a scale of 1 to 5 on the last day of each period. Silage DM intake (DMI) was estimated by the difference between the weight of the offered and rejected silage (Celis-Alvarez et al., 2016), expressed in kg DM $cow^{-1}$ $d^{-1}$.

The chemical composition of milk (fat, protein and lactose) was determined with an ultrasound milk analyzer (Model MCC, Lactoscan, Nova Zagora, Bulgaria). Milk urea N (MUN) was also determined by the enzymatic colorimetric method described by Chaney and Marbach (1962).

Chemical composition analyses of silages included DM, organic matter (OM), calculated using the Daysi-ANKOM method, crude protein (CP) while N content was obtained using the Kjeldahl method, the result was multiplied by a factor of 6.25 (AFRC, 1993) to obtain the amount of crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), in vitro digestibility of DM (IVDMD) and estimated metabolizable energy (eME) were determined following standard procedures (Celis-Alvarez et al., 2017). The pH of silages was determined by dilution of silage in distilled water.

## Economic analysis

A partial budgeting method was used considering feeding costs and returns from milk sales between treatments (Celis-Alvarez et al., 2016).

## Experimental design and statistical analysis

Chemical composition variables were analyzed by ANOVA using a completely randomized experimental design, using the following model (Lawal, 2014):

$$Y_{ijk} = \mu + t_i + e_{ij}$$

where µ is the overall mean, t is the effect due to treatments and e is the experimental error.

Animal variables were analyzed with ANOVA using a 3×3 Latin square experimental design repeated twice. The allocation of treatment sequences and of cows to sequences within squares was randomized, following the model (Kaps and Lamberson, 2004):

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

where µ is the overall mean; S is the effect due to squares i = 1, 2; C is the effect due to cows within frames j = 1, 2, 3; P is the effect due to experimental periods k = 1, 2, 3; t is the effect due to treatments l = 1, 2, 3, and e is the experimental error.

Tukey's test was applied when differences in the ANOVA were significant ($P < 0.05$).

## RESULTS

### Herbage mass of crops and chemical composition of silages

The DM of wheat was 34% higher than that of maize (Table 1). Maize yield was 14400.5 kg DM $ha^{-1}$ and the mean height was 2.9 m.

**Table 1.** Yield, dry matter and height of wheat and maize crops. DM: Dry matter; HM: herbage mass.

| | DM | HM | HM $d^{-1}$ | Height |
|---|---|---|---|---|
| | g $kg^{-1}$ | kg DM $ha^{-1}$ | kg DM | m |
| Wheat | 359.1 | 5294 | 53.5 | 0.7 |
| Maize | 235.5 | 14400 | 116.5 | 2.9 |

In terms of chemical composition, there were significant differences ($P < 0.05$) for all silage variables, except for NDF and ADF ($P > 0.05$). The DM of WS was 14% and 35% higher compared to WMS and MS respectively. The OM content was higher in the MS treatment; on the other hand, CP was higher in the WS treatment. The MS treatment showed better quality to the rest of the treatments, in terms of higher values of IVDMD and eME (Table 2), but lower CP content.

As a pH lower than 4.0 is an indicator of sound fermentation and stability (Ali et al., 2015), MS was more stable with a pH of 3.9, compared to WS with a pH of 4.5 (Table 2).

**Table 2.** Chemical composition of silages. Different letters in the column indicate significant differences according to Tukey's test ($P < 0.05$). WS: Wheat silage; WMS: wheat-maize silage; MS: maize silage; SEM: standard error of the mean; DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; IVDMD: in vitro digestibility of DM; eME: estimated metabolizable energy.

| Variable | WS | WMS | MS | Mean | Commercial concentrate | SEM | P-value |
|---|---|---|---|---|---|---|---|
| DM, g $kg^{-1}$ | 393.0$^{a}$ | 336.5$^{b}$ | 257.3$^{c}$ | 328.9 | 922.1 | 11.72 | 0.000 |
| OM, g $kg^{-1}$ DM | 844.1$^{c}$ | 888.2$^{b}$ | 922.1$^{a}$ | 884.8 | 900.3 | 7.92 | 0.000 |
| CP, g $kg^{-1}$ DM | 81.1$^{a}$ | 79.9$^{a}$ | 74.4$^{b}$ | 78.5 | 182.1 | 2.70 | 0.033 |
| NDF, g $kg^{-1}$ DM | 582.9 | 561.7 | 545.3 | 563.3 | 176.5 | 24.48 | 0.192 |
| ADF, g $kg^{-1}$ DM | 327.1 | 335.6 | 305.9 | 322.9 | 50.6 | 19.87 | 0.190 |
| IVDMD, g $kg^{-1}$ DM | 579.5$^{b}$ | 607.6$^{a}$ | 629.3$^{a}$ | 605.5 | 878.3 | 15.83 | 0.003 |
| eME, MJ $kg^{-1}$ DM | 8.2$^{b}$ | 8.6$^{a}$ | 8.8$^{a}$ | 8.5 | 12.5 | 0.20 | 0.000 |
| pH | 4.5$^{a}$ | 3.9$^{b}$ | 3.8$^{b}$ | 4.1 | - | 0.10 | 0.000 |

### Animal variables

The results of the animal variables of milk yield and chemical composition, live weight, and body condition score, showed nonsignificant differences ($P > 0.05$) between treatments or between experimental periods (Table 3). For silage DM intakes there were nonsignificant differences ($P > 0.05$) between treatments, but there were significant differences between experimental periods for SDMI and TDMI (Table 4), where experimental period 3 showed higher intakes ($P < 0.05$).

**Table 3.** Animal variables of milk yield and chemical composition, milk urea N, live weight and body condition score of treatments and by experimental period. WS: Wheat silage; WMS: wheat-maize silage; MS: maize silage; SEM T: standard error of the mean of the treatments; SEM EP: SEM of experimental periods; MY: milk yield; MUN: milk urea N; LW: live weight; BCS: body condition score.

| | Treatments | | | | | Experimental periods | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | WS | WMS | MS | SEM T | P-Value | P1 | P2 | P3 | SEM EP | P-value |
| MY, kg cow$^{-1}$ d$^{-1}$ | 14.9 | 14.8 | 16.6 | 0.49 | 0.06 | 15.2 | 15.6 | 15.5 | 0.49 | 0.82 |
| Milk fat, g kg$^{-1}$ | 33.5 | 33.9 | 33.7 | 1.01 | 0.97 | 34.0 | 32.7 | 34.3 | 1.01 | 0.50 |
| Milk protein, g kg$^{-1}$ | 30.6 | 30.6 | 30.4 | 0.17 | 0.63 | 30.5 | 30.3 | 30.8 | 0.17 | 0.27 |
| Lactose, g kg$^{-1}$ | 45.9 | 46.0 | 45.7 | 0.25 | 0.72 | 45.8 | 45.6 | 46.2 | 0.25 | 0.20 |
| MUN, mg dL$^{-1}$ | 11.5 | 11.9 | 10.2 | 0.57 | 0.14 | 10.1 | 11.6 | 11.9 | 0.57 | 0.57 |
| LW, kg | 477.9 | 478.8 | 487.0 | 4.00 | 0.27 | 475.9 | 484.8 | 483.0 | 4.00 | 0.31 |
| BCS, 1-5 | 2.1 | 2.1 | 2.2 | 0.10 | 0.79 | 2.2 | 2.1 | 2.1 | 0.10 | 0.79 |

**Table 4.** Dry matter intake. Different letters in the row indicate significant differences according to Tukey's test ($P < 0.05$). WS: Wheat silage; WMS: wheat-maize silage; MS: maize silage; SEM T: standard error of the mean of the treatments; SEM EP: SEM of experimental periods; CC: commercial concentrate; SR: silage refusal; SDMI: silage DM intake; TDMI: total DM intake.

| | Treatments | | | | | Experimental periods | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | WS | WMS | MS | SEM T | P-Value | P1 | P2 | P3 | SEM EP | P-value |
| CC, kg DM cow$^{-1}$ d$^{-1}$ | 4.60 | 4.6 | 4.6 | - | - | 4.60 | 4.6 | 4.6 | - | - |
| SR, kg DM cow$^{-1}$ d$^{-1}$ | 1.9 | 2.0 | 1.9 | - | - | 2.2 | 1.9 | 1.7 | - | - |
| SDMI, kg DM cow$^{-1}$ d$^{-1}$ | 7.9 | 7.8 | 7.9 | 0.08 | 0.11 | 7.6$^{c}$ | 7.9$^{b}$ | 8.1$^{a}$ | 0.08 | 0.00 |
| TDMI, kg DM cow$^{-1}$ d$^{-1}$ | 12.5 | 12.4 | 12.5 | 0.06 | 0.47 | 12.2$^{c}$ | 12.5$^{b}$ | 12.7$^{a}$ | 0.06 | 0.06 |

The cost analysis of the treatments showed that in MS, the cost of silage was lower compared to the other treatments during the experiment and higher margin over feed costs compared to WMS by 13% and 20% with WS (Table 5).

**Table 5.** Feeding costs and returns. WS: Wheat silage; WMS: wheat-maize silage; MS: maize silage.

| | WS | WMS | MS |
|---|---|---|---|
| Feeding costs | | | |
| Commercial concentrate, US$ | 162.27 | 162.27 | 162.27 |
| Silages, US$ | 60.32 | 42.24 | 39.10 |
| Total feeding costs, US$ | 222.59 | 204.51 | 201.40 |
| Incomes | | | |
| Total milk production, kg, 42 d | 1251.80 | 1246.20 | 1394.70 |
| Milk selling price, US$ | 0.30 | 0.30 | 0.30 |
| Income from milk sales, US$ | 373.31 | 371.63 | 415.91 |
| Total margin over feeding costs, US$ | 150.72 | 167.12 | 214.50 |
| Feeding costs, US$ kg$^{-1}$ milk | 0.18 | 0.16 | 0.15 |
| Margin over feeding costs, US$ kg$^{-1}$ milk | 0.12 | 0.13 | 0.15 |
| Income/feeding costs, US$ | 1.70 | 1.80 | 2.16 |

## DISCUSSION

### Chemical composition of silage

The herbage mass of the wheat crop was 5294 kg DM $ha^{-1}$, lower than reported by Vega-García et al. (2021) with 5419 kg DM $ha^{-1}$, likewise, the mean height was 0.7 m, lower than reported by Vega-García et al. (2021) with 0.8 m. The phenological stage of the crop must be taken into account in the ensiling process, since during the flowering stage the DM content is low, but the concentration of soluble carbohydrates is high, while during the milk-ripe phenological stage the DM increases, but the concentration of soluble carbohydrates decreases, which in turn reduces the risk of undesirable fermentations (Filya, 2003).

The wheat forage prior to ensiling had DM of 359.1 g $kg^{-1}$, close to that reported by Filya (2003) with 366 g $kg^{-1}$ at a milk stage of the wheat crop, suitable to obtain a good ensiling process, as Xia et al. (2018) mention the phenological stage when a higher nutritional quality is obtained is during the milk and the milk-ripe stage, which is high in sugars and protein, with a DM content of 30% to 35% that allows a successful silage. On the contrary, DM value for maize prior to silage was 235.5 g $kg^{-1}$, despite this value that can be considered medium ensilability according to Martínez-Fernández et al. (2013), the ensiling process was adequate.

The nutritive value of silage is influenced by several factors, such as maize variety, agronomic factors (soil type, fertilization), and growing conditions (water availability, temperature, irradiation), phenological stage at harvest, harvesting practices, as well as ensiling conditions (Khan et al., 2015). Similarly, changes in nutrient components will occur as the plant matures, with a decrease in the nutritive value of the cell wall, as well as a decrease in cell content (Filya, 2003).

Four stages are described within the silage process: An initial aerobic phase in the silo after harvest, the fermentation phase, the stable storage phase in the silo and the feed-out phase, the latter of which involves opening the silo, when the silage is exposed to the air (Wilkinson and Davies, 2012). After silo opening, DM values were 393 g $kg^{-1}$ for WS and 260.8 g $kg^{-1}$ for MS similar to the DM, which increased from the initial value, reflecting a restriction in fermentation degree and a higher concentration of soluble carbohydrates in the resulting silage (Wilkinson and Davies, 2012).

The OM for the MS treatment was 926.3 g $kg^{-1}$ DM, which is above that reported by Sainz-Ramírez et al. (2021) with 927 g $kg^{-1}$ $DM^{-1}$, WS mean was 844.1 g $kg^{-1}$ DM, lower than that reported by Xia et al. (2018) with 937.6 g $kg^{-1}$ DM for wheat silage. This difference could be due to silage deterioration caused by exposure to air, which results in reduced nutritive value, attributed to the loss of fermentation products that are potentially digestible substrates (Wilkinson and Davies, 2012).

Within CP, the mean for the WS treatment was 81.1 g $kg^{-1}$ DM, value lower than that reported by Xia et al. (2018) with 94.9 g $kg^{-1}$ DM for wheat silage. The MS CP content had a mean of 74.4 g $kg^{-1}$ DM, lower than that reported by Sainz-Ramírez et al. (2021) with 86 g $kg^{-1}$ DM and Albarrán et al. (2012) with 79.9 g $kg^{-1}$ DM, where Xia et al. (2018) mentioned in regard to CP that there can be degradation and loss in the silage if there is a more extensive fermentation due to the presence of high moisture in the forage during the ensiling process, both silages have a low protein intake, hence the need to supplement the cows with commercial concentrate.

Mean NDF and ADF were higher than reported by Xia et al. (2018) with 411.2 and 235.4 g $kg^{-1}$ DM for wheat silage respectively, similarly results were also higher than reported by Sainz-Ramírez et al. (2021) with 505 and 231 g $kg^{-1}$ DM for maize silage respectively. The high NDF values observed can be related to the limited fermentation in the ensiling process (Xia et al., 2018).

Regarding forage digestibility, its value will be a function of NDF and energy concentration, since the higher the amount of non-fibrous carbohydrates, the more energy for forage colonization by rumen microbiota (Zhang et al., 2020). The IVDMD and eME values for the WS treatment were 579.5 g $kg^{-1}$ DM and 8.2 MJ $kg^{-1}$ DM, lower than what reported by Xia et al. (2018) with 691.5 g $kg^{-1}$ DM and 9.8 MJ $kg^{-1}$ DM for wheat silage respectively, on the contrary, values for MS in terms of IVDMD and eME were lower than reported by Sainz-Ramírez et al. (2021) with 708 g $kg^{-1}$ DM and 10.5 MJ $kg^{-1}$ DM respectively.

Acidity, indicated by pH, is a factor that will be dependent on the DM present in the forage, as the lower the DM there will be a slow decrease in pH (König et al., 2017). In the present study, the mean pH for the WS treatment was higher than reported by Xia et al. (2018) with 4.0, and for MS the mean pH was 3.8, close to that reported by Sainz-Ramírez et al. (2021) with 3.9. Ali et al. (2015) considered a suitable pH value of 4.0 for a stable silage, although there are factors that will influence the rate of pH decrease, such as the silage temperature that will affect the time needed to reach a final low pH, which, in turn, this period and the final pH will influence the degradability of the silage in the rumen. The higher pH of the WS treatment could be due to lactic acid metabolism by aerobic bacteria, which have less acidic end products, which will also lead to carbohydrate and protein losses (Wilkinson and Davies, 2012). On the other hand, the pH decrease in silages resulting from microbial fermentation may decrease CP degradation (Xia et al., 2018).

**Productive response of dairy cows**

Milk yields of cows fed small grain cereal silage for small-scale milk production systems in the study area range from 15.2 to 16.5 kg milk cow$^{-1}$ d$^{-1}$ during the dry season (Becerril-Gil et al., 2018; Vega-García et al., 2020), higher than reported in this study. For maize silage, yields of 10.6 to 16.0 kg milk cow$^{-1}$ d$^{-1}$ have been reported (Becerril-Gil et al., 2018; Sainz-Ramírez et al., 2021), where MS milk yields are within this range. For diets that include silage mixture of two crops (oats-maize) the mean yield ranges from 15 to 16 kg milk cow$^{-1}$ d$^{-1}$ (Becerril-Gil et al., 2018), close to that reported for WMS.

The mean milk fat was 33.5 g kg$^{-1}$ for WS, higher than reported by Vega-García et al. (2020), but lower than Becerril-Gil et al. (2018) for cows fed black oat silage, the mean for MS was similar to that reported by Albarrán et al. (2012) with 33.8 g kg$^{-1}$. Regarding protein and lactose in milk for WS it was below that reported by Vega-García et al. (2020) with 32.3 and 46.6 g kg$^{-1}$ respectively. For protein in milk, in MS it was lower than reported by Albarrán et al. (2012) with 32.2 g kg$^{-1}$, in lactose the value was lower than reported by Becerril-Gil et al. (2018). In turn, Costa et al. (2019) stated mean lactose values of 47 g kg$^{-1}$ for cow's milk, which are close to the values here reported. The fat, protein and lactose values of the treatments are within limits of the Mexican standards for raw milk.

The MUN value is used as a non-invasive way to estimate N excretion in dairy cows (Kohn et al., 2002), which is considered as an indicator of the efficiency of N utilization in the diet of dairy cows, with ranges of 11 to 18 mg dL$^{-1}$ and 10 to 14 mg dL$^{-1}$ (Powell et al., 2011). The means for the treatments are within these ranges. This suggests adequate feed protein content and efficiency.

**Dry matter intake**

Silage quality will have a major impact on silage intake, although it is difficult to predict silage intake based on silage quality alone, as other factors such as supplementation and milk production must be considered (Hetta et al., 2007).

Some authors mention that the higher the digestibility of a feed, the higher the DM intake (Hetta et al., 2007), and the available energy will be reflected which indicates the quality of feed (Hetta et al., 2007), which is not shown in the present study, since although the WS treatment had lower digestibility than the MS treatment, neither the intake nor the milk yield were affected.

Dry matter intake of silage increases with increasing forage maturity prior to ensiling with a DM content of 300-350 g kg$^{-1}$, on the contrary, it decreases with high forage moisture content, which could be limited by the end products of fermentation (Khan et al., 2015), which was not present in the study as the MS treatment had lower DM content compared to WS, which did not affect the consumption of these silages. Another factor to consider in terms of DMI is the proportion of NDF that is not digested in the rumen, which could limit the rate of passage of forages from the rumen, thus limiting intake (Zhang et al., 2020). Silage DM intake represented nearly 80% total DM offered, which after refusals represented 63% DM intake, with no differences among treatments. The proportion of forage in the final intake was lower than that reported by Vega-García et al. (2020) with a 70% intake of small grain cereal silage and with respect to Albarrán et al. (2012) with a 72% intake of maize silage.

## Cost analysis

Partial budgets were used to compare feeding costs as well income over feed costs is considered as an indicator of the profitability of a farm (Prospero-Bernal et al., 2017). All three treatments showed positive margins over feed costs, which as stated by Sainz-Ramírez et al. (2021), a high proportion of roughage in the diet of cows reduces costs and increases incomes.

However, feed costs were lower in MS, which is due to the higher DM production of forage from the maize crop, these costs were close to WMS and 10% less compared to WS. Income from milk sales was similar in MS and WMS, but lower than WS by 10%. Income over feed costs was higher in MS with 2.1, which was 19% higher than those reported by Sainz-Ramírez et al. (2021) with 1.7, for WMS and WS they were similar with 1.8 and 1.7, respectively, which were 17% higher than those reported by Gómez-Miranda et al. (2020b) for barley silage alone and in mixture with a value of 1.49, these results indicate that the inclusion of MS was more profitable compared to WS and WMS.

# CONCLUSIONS

The results showed that there were significant differences between treatments with respect to chemical composition and pH of silages, which did not affect milk yield and intakes of dairy cows fed wheat silage, maize silage and the mixture of wheat silage and maize silage.

The use of wheat silage increased feeding costs, however, all three treatments had positive margins on feeding costs and the use of wheat silage may be an option when climatic conditions do not allow the maize crop to grow adequately or to be harvested in time.

### Author contributions

Conceptualization: F.L-G., C.M.A-J. Methodology: C.D.A-G., F.L-G., J.G.E-F., Validation: F.L-G., C.M.A-J. Data curation: F.L-G. Writing-original draft: C.D.A-G., F.L-G., J.G.E-F, C.M.A-J., Writing-review & editing: C.D.A-G., F.L-G., C.M.A-J., Supervision: C.M.A-J. Funding acquisition: F.L-G.

### Acknowledgements

The authors express their gratitude to the farmer who participated in this experiment, respecting his and his family's privacy by not disclosing their names. This work was carried out with funding from the Autonomous University of the State of Mexico (Universidad Autónoma del Estado de México) through UAEM grant number 6236/2020CIB, and from the Mexican National Council for Science and Technology (CONACYT- Consejo Nacional de Ciencia y Tecnología) for the postgraduate grant of Cloe Dafne Alvarez-García.

### References

AFRC. 1993. Energy and protein requirements for ruminants. Agricultural Food and Research Council (AFRC). CAB International, Wallingford, UK.

Albarrán, B., García, A., Espinoza, A., Espinosa, A., Arriaga, C.M. 2012. Maize silage in the dry season for grazing dairy cows in small scale production systems in the Mexico's Highlands. Indian Journal of Animal Research 46(4):317-324.

Ali, M., Cone, J.W., Khan, N.A., Hendriks, W.H., Struik, P.C. 2015. Effect of temperature and duration of ensiling on *in vitro* degradation of maize silages in rumen fluid. Journal of Animal Physiology and Animal Nutrition 99:251-257. doi:10.1111/jpn.12244.

Becerril-Gil, M.M.N., López-González, F., Estrada-Flores, J.G., Arriaga-Jordán, C.M. 2018. Black oat (*Avena strigosa*) silage for small-scale dairy systems in the highlands of central Mexico. Tropical and Subtropical Agroecosystems 21:467-476.

Celis-Alvarez, M.D., López-González, F., Estrada-Flores, J.G., Domínguez-Vara, I.A., Heredia-Nava, D., Munguía-Contreras, A., et al. 2017. Evaluación nutricional *in vitro* de forrajes de cereales de grano pequeño para sistemas de producción de leche en pequeña escala. Tropical and Subtropical Agroecosystems 20:439-446.

Celis-Alvarez, M.D., López-González, F., Martínez-García, C.G., Estrada-Flores, J.G., Arriaga-Jordán, C.M. 2016. Oat and ryegrass silage for small-scale dairy systems in the highlands of central Mexico. Tropical Animal Health and Production 48:1129-1134. doi:10.1007/s11250-016-1063-0.

Chaney, A.L., Marbach, E.P. 1962. Modified reagents for determination of urea and ammonia. Clinical Chemistry 8:130-132.
Conroy, C. 2005. Participatory livestock research. ITDG Publishing, Bourton-on-Dunsmore, Warwickshire, UK.
Costa, A., López-Villalobos, N., Sneddon, N.W., Shalloo, L., Franzoi, M., De Marchi, M., et al. 2019. Invited review: Milk lactose—Current status and future challenges in dairy cattle. Journal of Dairy science 102(7):5883-5898. doi:10.3168/jds.2018-15955.
Filya, I. 2003. Nutritive value of whole crop wheat silage harvested at three stages of maturity. Animal Feed Science and Technology 103:85-95. doi:10.1016/S0377-8401(02)00284-5.
Gómez-Miranda, A., Estrada-Flores, J.G., Morales-Almaraz, E., López-González, F., Flores-Calvete, G., Arriaga-Jordán, C.M. 2020b. Barley or black oat silages in feeding strategies for small-scale dairy systems in the highlands of Mexico. Canadian Journal of Animal Science 100:221-227. doi:10.1139/cjas-2018-0237.
Gómez-Miranda, A., Vega-García, J.I., Narvaez-Uribe, O., Morales-Almaraz, E., López-González, F., Arriaga-Jordán, C.M. 2020a. Evaluación de un concentrado de pasta de canola y mazorca de maíz para vacas lecheras en pastoreo de pastizales nativos en los valles altos de México. Tropical and Subtropical Agroecosystems 23(58):1-9.
Hemme, T., Otte, J. 2010. Status and prospects for smallholder milk production a global perspective. Food and Agriculture Organization of The United Nations (FAO), Rome, Italy. Available at https://www.researchgate.net/publication/280736807_Status_and_Prospects_for_Smallholder_Milk_Production_-_A_Global_Perspective (accessed June 2022).
Hernández, N., Soto, F., Plana, R. 2015. Comportamiento del crecimiento y rendimiento del cultivo del trigo (*Triticum aestivum* L.) en tres fechas de siembra. Cultivos tropicales 36:86-92.
Hetta, M., Cone, J.W., Bernes, G., Gustavsson, A.M., Martinsson, K. 2007. Voluntary intake of silages in dairy cows depending on chemical composition and in vitro gas production characteristics. Livestock Science 106:47-56. doi:10.1016/j.livsci.2006.06.013.
Kaps, M., Lamberson, W. 2004. Change-over designs. p. 294-312. In Kaps, M., and Lamberson, W. (eds.) Biostatistics for animal science. Cromwell Press, Trowbridge, UK.
Khan, N.A., Yu, P., Ali, M., Cone, J.W., Hendriks, W.H. 2015. Nutritive value of maize silage in relation to dairy cow performance and milk quality. Journal of the Science of Food and Agriculture 95(2):238-52. doi:10.1002/jsfa.6703.
Kohn, R.A., Kalscheur, K.F., Russek-Cohen, E. 2002. Evaluation of models to estimate urinary nitrogen and expected milk urea nitrogen. Journal of Dairy Science 85:227-233. doi:10.3168/jds.S0022-0302(02)74071-X.
König, W., Lamminen, M., Weiss, K., Tuomivirta, T.T., Sanz, S., Fritze, H., et al. 2017. The effect of additives on the quality of white lupin–wheat silage assessed by fermentation pattern and qPCR quantification of clostridia. Grass and Forage Science 72(4):757-771. doi:10.1111/gfs.12276.
Lawal, B. 2014. Applied statistical methods in agriculture, health and life sciences. Springer, Cham, Switzerland.
López-González, F., Rosas-Dávila, M., Celis-Alvarez, M.D., Morales-Almaraz, E., Domínguez-Vara, I.A., Arriaga-Jordán, C.M. 2017. Milk production under grazing of different pasture grasses in small-scale dairy systems in the highlands of central Mexico. Journal of Livestock Science 8:92-97.
Martínez-Fernández, A., Argamentería-Gutiérrez, A., De la Roza, B. 2014. Manejo de forrajes para ensilar. Editado por: Servicio Regional de Investigación y Desarrollo Agroalimentaria (SERIDA) del Principado de Asturias, Villaviciosa, Asturias, España. Available at http://www.serida.org/publicacionesdetalle.php?id=6079 (accessed May 2022).
Martínez-Fernández, A., Soldado, A., de la Roza-Delgado, B., Vicente, F., Gonzalez-Arrojo, M.A., Argamenteria, A. 2013. Modelling a quantitative ensilability index adapted to forages from wet temperate areas. Spanish Journal of Agricultural Research 11(2):455-462. doi:10.5424/sjar/2013112-3219.
Martínez-García, C.G., Rayas-Amor, A.A., Anaya-Ortega, J.P., Martínez-Castañeda, F.E., Espinoza-Ortega, A., Prospero-Bernal, F., et al. 2015. Performance of small-scale dairy farms in the highlands of central Mexico during the dry season under traditional feeding strategies. Tropical Animal Health and Production 47:331-337. doi:10.1007/s11250-014-0724-0.
OECD-FAO. 2022. The OECD-FAO Agricultural Outlook 2022-2031. Organization for Economic Cooperation and Development (OECD) and Food and Agriculture Organization (FAO) of the United Nations, Rome, Italy; Paris, France. Available at https://www.fao.org/documents/card/en/c/CC0308EN (accessed August 2022).
Posadas-Domínguez, R.R., Arriaga-Jordán, C.M., Callejas-Juárez, N., Martínez-Castañeda, F.E. 2013. Viabilidad económica y financiera de los sistemas lecheros de pequeña escala y el papel de la mano de obra familiar: Panorama económico 2010-2019. p. 221-232. In Nava, B. (ed.) La ganadería en la seguridad alimentaria de las familias campesinas. Universidad Autónoma Chapingo, Chapingo, Texcoco, México.

Powell, J.M., Wattiaux, M.A., Broderick, G.A. 2011. Short communication: Evaluation of milk urea nitrogen as a management tool to reduce ammonia emissions from dairy farms. Journal of Dairy Science 94(9):4690-4694. doi:10.3168/jds.2011-4476.

Prospero-Bernal, F., Martínez-García, C.G., Olea-Pérez, R., López-González, F., Arriaga-Jordán, C.M. 2017. Intensive grazing and maize silage to enhance the sustainability of small-scale dairy systems in the highlands of Mexico. Tropical Animal Health and Production 49(7):1537-1544. doi:10.1007/s11250-017-1360-2.

Sainz-Ramírez, A., Estrada-Flores, J.G., Morales-Almaraz, E., Flores-Calvete, G., López-González, F., Arriaga-Jordán, C.M. 2021. Effect of the inclusion of sunflower silage for cows in small-scale dairy systems in the highlands of Mexico. Journal of Livestock Science 12:95-102. doi:10.33259/JLivestSci.2021.95-102.

Stroup, W.W., Hildebrand, P.E., and Francis, C.A., 1993. Farmer participation for more effective research in sustainable agriculture. In Ragland, J., Lai, R. (eds.) Technologies for sustainable agriculture in the tropics. ASA Special Publication, Madison, Wisconsin, USA.

Vega-García, J.I., López-González, F., Estrada-Flores, J.G., Flores-Calvete, G., Prospero-Bernal, F., Arriaga-Jordán, C.M. 2020. Black oat (*Avena strigosa* Schreb.) grazing or silage for small-scale dairy systems in the highlands of central Mexico. Part I. Crop and dairy cow performance. Chilean Journal of Agricultural Research 80:515-525. doi:10.4067/S0718-58392020000400515.

Vega-García, J.I., López-González, F., Morales-Almaraz, E., Arriaga-Jordán, C.M. 2021. Grazed rain-fed small-grain cereals as a forage option for small-scale dairy systems in central Mexico. Tropical Animal Health and Production 53(5):511. doi:10.1007/s11250-021-02958-y.

Velázquez-Martínez, M., Garnica-Monzalvo, L., Vargas-Monter, J., Hernández-Martínez, R., Noguez-Estrada, J., Sifuentes-Saucedo, D.M., et al. 2022. Production of maize and sunflower forage, and its preference as silage among ewes in Mineral de la Reforma, Hidalgo. Agro Productividad 15(7):213-219. doi:10.32854/agrop.v15i7.2328.

Wilkinson, J.M., Davies, D.R. 2012. The aerobic stability of silage: Key findings and recent developments. Grass and Forage Science 68:1-19. doi:10.1111/j.1365-2494.2012.00891.x.

Xia, C., Liang, Y., Bai, S., He, Y., Rahman, A.U., Su, H., et al. 2018. Effects of harvest time and added molasses on nutritional content, ensiling characteristics and *in vitro* degradation of whole crop wheat. Asian-Australasian Journal of Animal Sciences 31(3):354-362. doi:10.5713/ajas.17.0542.

Zhang, Y., MacAdam, J.W., Villalba, J.J., Dai, X. 2020. *In vitro* digestibility of mountain-grown irrigated perennial legume, grass and forb forages is influenced by elevated non-fibrous carbohydrates and plant secondary compounds. Journal of the Science of Food and Agriculture 101(1):334-340. doi:10.1002/jsfa.10648.