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# BARLEY OR BLACK OAT SILAGES IN FEEDING STRATEGIES FOR SMALL-SCALE DAIRY SYSTEMS IN THE HIGHLANDS OF MEXICO

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# BARLEY OR BLACK OAT SILAGES IN FEDING STRATEGIES FOR SMALL-SCALE DAIRY SYSTEMS IN THE HIGHLANDS OF MEXICO

## ABSTRACT

High costs from external inputs in small-scale dairy systems, and possible effects of climate change, require forage alternatives as silage for the dry season from small-grain cereals that have short cropping cycles, winter hardiness, and good nutritional quality. The objective was to assess the provision of 10 kg DM/cow/day of barley (BLY) or black oat (BKO) silages in three treatments T1=100% BLY, T2=50% BLY + 50% BKO, T3=100% BKO for milking cows; that also received 4.6 kg DM/cow/day of concentrates, and access to pasture. Nine Holstein cows in groups of three were randomly assigned to a 3X3 Latin Square design repeated three times, with 14 day experimental periods. Measurements of animal variables and sampling for chemical analyses of feeds were the last four days of each period. Feeding costs were by partial budgets. There were no differences (P>0.05) for milk yield, milk fat and protein content, milk urea nitrogen, body condition score, or live weight. The cost of BLY silage was 8% less than BKO silage. T1 had the higher margin over cost of feeds followed by T2. Both silages alone or in combination are viable options for small-scale dairy systems, as there were no differences in performance or in feeding costs or margins.

**Keywords:** Feeding strategies; dairy cows; *Hordeum vulgare*; *Avena strigosa*; small-scale dairy systems; Mexico.

Dairy production in Mexico takes place in three distinct systems (specialized large scale, tropical or dual purpose, and small-scale dairy systems), under heterogeneous socioeconomic, agroecological, and technological conditions (Food and Agriculture Organization of the United Nations (FAO) and Pan American Dairy Federation (FEPALE). 2012). Mexico produces 12.2 million tons of cow milk per year; but Mexico is also the largest importer of non-fat dry milk with expected imports of 330 thousand tons in 2018 (Indexmundi, 2018).

Small-scale livestock systems have a large potential for development, both in terms of increasing their contribution to local and national food production, as for the improvement in the livelihoods of farming families; since demand for milk and meat is on the rise in the developing world (Herrero et al. 2013).

Around 35% of milk production in Mexico comes from small-scale dairy systems (SSDS), defined as small farms with herds between 3 and 35 cows plus replacements that rely on family labour (Prospero-Bernal et al. 2017), that contribute to overcome rural poverty of farming families (Espinoza-Ortega et al. 2007),

However, these small-scale systems have high costs due to a high reliance on external inputs such as commercial compound concentrates, straws, and hays that limit their sustainability (Fadul-Pacheco et al. 2013; Prospero-Bernal et al. 2017). In addition, possible effects of climate change may bring about a reduction or change in the pattern of rains, and higher frequency of extreme events (Intergovernmental Panel on Climate Change, 2014).

Implementation of maize silage in small-scale dairy farms for the dry season (November to April in Mexico) reduced feeding costs and increased margins (Prospero-Bernal et al. 2017); but maize requires a long growing cycle and sufficient rainfall to thrive, which may not be the case in future scenarios.

Thornton et al. (2009) established the need for research in forage crops better adapted to possible effects of climate change that enable livestock farmers to better cope with future scenarios.

Therefore, small-scale dairy systems need forage alternatives to reduce external inputs since relying on farm grown forages increased the profitability of small-scale dairy farms (Prospero-Bernal et al. 2017); and that these forage alternatives are adaptable to possible future scenarios of low rainfall providing good quality feed particularly for the pronounced dry season (November to April in Mexico).

Whole-crop small grain cereals conserved as silage are a potential alternative to meet these requirements given their short cropping cycle requiring less water, winter hardiness for late or autumn sowing, and good nutritional quality (Burbano-Muñoz et al. 2018). Small grain cereals include wheat, triticale, rye, barley and oats among others (Payne et al. 2008).

Forage barley (*Hordeum vulgare* L.) is a resistant crop with good potential for quality silage for dairy herds (Newton et al. 2011, Nikkhah 2013). Its rapid growth can eliminate weed competition, resulting in high yields (Sadeghpour et al. 2013).

Black oat (*Avena strigosa* Schreb.) is a promising forage alternative characterised by high forage yields and tillering capacity, short growth cycle, and good regrowth potential (Dial 2014; Sánchez-Gutiérrez et al. 2014).

There is scarce literature on the potential of barley or black oat as forage sources in Mexico, and no reports on their use in small-scale dairy systems. Therefore, the objective was to evaluate silages from barley (*Hordeum vulgare* cv Cerro Prieto) or black oat (*Avena strigosa* cv Saia) alone or in mixture as the main forage source for milking dairy cows in small-scale dairy systems.

# MATERIALS AND METHODS

## Study area

Work followed a participatory livestock research approach (Conroy, 2005) with four participating farmers. The four participating farmers are brothers, and manage the land of their small farms as a single unit. All cows graze together. When not grazing and over-night, cows are confined in three pens (two brothers share one pen and manage their cows as one herd), so that there were three herds. Hand milking and feeding of concentrates and silages takes place in each pen.

The farms are located in the municipality of Aculco in the State of Mexico at 20°12’58”N and 99°57´2”W. Altitude is 2235 m, a sub-humid temperate climate with 800 mm of rain in summer (May-October) with a pronounced dry season (November – April) and mean annual temperature of 13.2°C. Fadul-Pacheco et al. (2013) described the area and the small-scale dairy systems.

## Experimental cows

The experiment ran from 6 February to 19 March 2016 with nine Holstein multiparous cows selected from the farmers’ herds. Three selected cows from each of the three herds constituted each ‘square’ in a 3x3 Latin Square design repeated three times.

Cows were selectedwith comparable number of calvings, mean live weight of 494±62.7 kg and 87±47.5 days in milk, and mean daily milk of 17±5.6 kg/milk/cow/day. Cows were grouped in ‘squares’ of three cows each similar in live weight, days in milk, and pre experimental milk yields.

Experimental cow management and field work with participating farmers followed accepted procedures of Universidad Autónoma del Estado de México.

Treatments were the provision of 10 kg DM/cow/day of either barley (BLY) or black oat (BKO) silages in three treatments T1 = 100% BLY, T2= 50% BLY + 50% BKO, T3= 100% BKO in the dry season. Estimating a daily voluntary intake of 15 kg DM/cow, silages provided around 66% of voluntary intake. Cows also received 4.6 kg DM/cow/day of a 19% CP dairy concentrate, and had access for 8 h to pasture. Pasture intake was calculated to be only a complement to the silage: concentrate diets.

## Animal variables

Milking was by hand at 0600 and 1800 h. Milk yield was weighed daily during sampling days with a clock spring balance with a 20 kg capacity. Samples of milk were taken at each milking during the last four days of each experimental period and aliquots used to determine concentration of milk fat, protein and lactose with an ultrasound milk analyser; using means for analyses. Milk urea nitrogen (MUN) was determined following Chaney and Marback (1962).

Live weight (kg/cow) with an electronic weighbridge, and body condition score (BCS) on a 1-5 scale, were recorded at the end of experimental periods.

## Forage crops

Barley (*Hordeum vulgare* cv Cerro prieto) and black oat (*Avena strigosa* cv Saia) were sown in 7 July 2016 on 2.5 ha each under rainfed conditions at 120 kg/ha of seed and fertilization of 82-46-00 and 80-60-40 NPK, for barley and black oat respectively. Fertilization of the barley crop followed recommendations by the Mexican National Agricultural, Forestry, and Livestock Research Institute (INIFAP) that developed the Cerro Prieto variety. Fertilization of the Saia black oat crop followed Sánchez-Gutiérrez et al. (2014).

Half the nitrogen and all the phosphorus and potassium were applied at sowing, and half the nitrogen 15 days post sowing. Half the area for each crop was sown with 8 kg/ha of red clover (*Trifolium pratense* cv. Kenland) to be used after ensiling. Given its very low growth, there was no red clover in the silages.

Harvest for ensiling in ground silos was at 67 days post sowing with a chopper harvester, cutting six 1.0 m$^2$ quadrants to ground level with hand shears before ensiling to estimate herbage yield. Silos fermented for 147 days after harvest.

## Pasture

Cows had restricted access for 8 h to continuously graze a multispecies pasture sown on 1.75 ha in spring 2015, with limited irrigation available during the dry season. Grass species sown at 30 kg seed/ha were *Festulolium* cv Spring Green, *Lolium perenne* cv Bargala and *Lolium perenne* cv Pay Day, together with 3.0 kg/ha of white clover (*Trifolium repens* cv Ladino), fertilized with 60-80-60 NPK kg/ha at sowing and 23 kg N/ha every four weeks thereafter.

Net Herbage Accumulation (NHA) in pasture was estimated following Hoogendoorn *et al.* (2016) by cutting to ground level 0.40 x 0.40 m quadrants outside and inside 0.5 x 0.5 m exclusion cages at the beginning and end of experimental periods; and compressed grass height was recorded with a rising plate grass metre (Celis-Alvarez et al. 2016).

## Chemical composition of feeds

Silage and pasture hand-plucked samples simulating grazing, were taken at the end of experimental periods. Silage pH was measured  in silage juice diluted in distilled water. Chemical analyses for DM, OM, CP, NDF, ADF, and in vitro OM digestibility (IVOMD) followed standard procedures as described by Celis-Alvarez et al. (2016). Starch determination was with the Megazyme Total Starch Assay kit.

Estimated Metabolizable Energy (eME) was calculated from Agricultural and Food Research Council - AFRC (1993) taking the *in vitro* digestibility of organic matter (IVDOM).

Silage offered and refused was recorded daily during the last four days of experimental periods, and means used in analyses. Estimation of herbage intake from pasture was from utilized ME following Hernández-Mendo and Leaver (2006)**.**

## Economic analysis

Feeding costs and profit margins were calculated with partial budgets (Harper et al., 2013), Only feeding costs and income from milk sales were considered in the analysis. It included maintenance costs (irrigation and fertilization) of pastures, and the establishment cost amortized over three years following (Prospero-Bernal et al. 2017).

## Experimental design and statistical analyses

The experiment was a 3x3 Latin Square design repeated three times (Kaps and Lamberson 2004), with treatment sequences (rows) assigned randomly for squares 1 and 3, and square 2 as a mirror image of square 1 to reduce carry over effects (Celis-Alvarez et al. 2016). Cows within squares were also assigned randomly to treatment sequence.

Three selected cows from each of the three herds constituted each ‘square’ in the 3x3 Latin Square design repeated three times, so that the square factor in the statistical model of analyses took account of variability among herds (farms).

Experimental periods were 14 days (10 days for adaptation and 4 days for sampling), following Pérez-Ramírez et al. (2012). Meier et al. (2012) mentioned that adaptation periods between 6 and 14 days are adequate for ruminants when changes in feeding are not drastic.

The statistical model was (Celis-Alvarez et al. 2016):

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

Where: μ = General mean; S = effect due to squares. i = 1, 2, 3; C = effect due to cows in squares j = 1, 2, 3; P = effect due to experimental periods. k = 1, 2, 3; t = effect due to treatment. L = 1, 2, 3; and *e* = residual error term. Tukey's test was applied if statistical differences were found ($P<0.05$).

## RESULTS

### Forage yields

Due to its fast growth rate, barley was in the milk-dough growth stage at 67 days post sowing when harvested for silage, with a yield of 3.8 t DM/ha. In contrast, black oat was at the heading stage, yielding 3.4 t DM/ha; 11% less than barley.

The multispecies pasture had a low NHA of 715 kg DM/ha over the experiment, representing a daily NHA of 17 kg DM/ha, with a mean compressed sward height of 2.5 cm, resulting in difficult grazing conditions.

### Chemical composition of feeds

The different growth stages of barley and black oat at ensiling showed differences in chemical composition of the silages (Table 1). BLY had 8% higher DM content, but 67% higher starch content and 12% higher ADF. This higher ADF content meant that BKO had 22% higher IVOMD, and a corresponding higher eME.

### Animal variables

Silage dry matter intake in T1 and T2 were significantly lower ($P<0.05$) than in T3. This was reflected in a significantly higher intake of pasture ($P<0.05$) in T1 than T3, with T2. Total DM intake was significantly higher in T1 and T3 than in T2 (Table 2).

Nonetheless, milk yields, milk fat and protein, and MUN contents were not significantly different among treatments ($P>0.05$). Lactose was higher in T1 than in T2 or T3 ($P<0.05$) (Table 3).

### Economic analysis

Costs for commercial concentrate and pasture were the same for all treatments. Concentrate allowance was the same for all cows with no refusals. The cost of pasture was calculated per grazing day/ha during the year and divided by the number of cows. This enabled to better assessment the cost of the silage treatments.

T3 (BKO) had a significantly higher silage and total feeding costs ($P<0.01$) than T1 (BLY) or T2 (BLY+BKO), but there were no differences ($P>0.05$) in profit margins per kg of milk or over feeding costs, nor in the cost/benefit ratio (Table 4).

## DISCUSSION

The use of silages during the dry season in Mexico is a feeding alternative that SSDS have to overcome feed scarcity due to lack of rain and the limited provision of irrigation for pastures.

This was the case for pastures in this experiment that showed low NHA, lower than reported by Burbano-Muñoz et al. (2018) in the same area, who recorded 42 kg DM/ha/day.

Together with low sward height, grazing conditions were difficult so that herbage intake was low and only complemented the silages and concentrate intake.

Small-grain cereals are an attractive forage option for SSDS given their short growing cycle that overcomes low rainfall or short rainy season and lack of irrigation. Small-grain cereals are also adapted to a wide range of soils and climates.

Under very different agroclimatic conditions, De Ruiter et al. (2002) in temperate New Zealand, and Sadeghpour et al. (2013) in semi-arid conditions in Iran, reported barley forage yields of 3.5 t DM/ha and 3.8 t DM/ha under rainfed conditions, similar to yields obtained in this work.

The slightly higher yield of barley may be due to a more advanced growth stage at cutting compared to black oat. The yield of black oat at 3.4 t DM/ha was similar to that reported by David et al. (2010) from work in Brazil, at a similar growth stage, indicating a good forage yield representing a growth rate of 52 kg DM/day.

Forage yield of barley at 57 kg DM/ha/day and black oat at 51 kg DM/ha/day showed their potential in the feeding strategies in SSDS during the dry season. The nutritional content of forages varies due to a number of factors as variety, soil nutrient availability and soil type, temperature, light interception and phenological stage (Kennelly y Weinberg 2013).

Wholecrop small-grain cereal silages, as barley or oat, are characterised by higher crude protein levels as reported by Benchaar et al. (2014) in barley silage with 90 g CP/kg DM, or 198 g CP/kg DM for black oat forage reported by Salgado et al. (2013) in Vietnam. These values are higher than between 64 and 80 kg CP/kg DM in maize silage (Anaya-Ortega et al. 2009, Al-Marashdeh et al. 2016).

However, CP content for BLY and BKO silages were as low as for maize silage, but similar as reported by David et al. (2010) for black oat forage with CP contents of 65 g/kg DM.

ADF content increases at advanced phenological stages, which explains the higher ADF content of BLY, was reflected in a lower *in vitro* digestibility than BKO; and the significantly lower intake of barley silage in T1 and T2.

The higher ADF content in BLY was reflected in a lower IVOMD, which may explain the lower BLY intake in T1. The higher starch content might have reduced the fermentation intensity in the silage (Kennelly y Weinberg 2003) resulting in a pH 0.2 units higher in BLY than BKO (Table 1).

IVOMD in BKO was similar to work by David et al. (2010) who reported values ranging from 601 to 694 g/kg DM for different varieties of black oat at the same growth stage. However, IVOMD for BLY were lower than reports by Aguilar-López et al. (2013) in Mexico, and Benchaar et al. (2014) in Canada.

In spite of different IVOMD between BLY and BKO, there were no statistical differences (P>0.05) for most animal variables whether silages were offered on their own or as a 50% BLY and 50% BKO mixture in T2. The higher starch content in BLY may explain the fact that in spite of lower IVOMD and lower silage DM intake, the ME content might have been higher than estimated.

Animal performance was similar to reports by Celis-Alvarez et al. (2016) but lower to findings by Burbano-Muñoz et al. (2018), both investigating the implementation of common oat (*Avena* *sativa*) silage for dairy cows in SSDS. Burbano-Muñoz et al. (2018) reported higher pasture intakes of a high quality herbage, reflected in higher milk yields.

Milk fat content was not different (P>0.05) but low in all treatments, just under 30 g/kg established by Mexican standards for raw milk. This might be explained by the low protein content of silages, therefore a low level of rumen degradable protein and reduced ruminal ammonia to completely degrade fibre and generate enough substrate for milk fat synthesis (Cerón and Correa, 2005).

Although lactose content showed differences (P<0.05), with higher values for T2 and T3 that included BKO, than T1 of BLY, the difference is less than 1 g/kg. Lactose is the most stable milk component; and there is little evidence of the effect of different diets on the lactose content of milk (Jenkins and McGuire 2006).

MUN contents were low, related to the low protein content of silages. Calculated CP content of total dry matter intake (DMI) was 121 g CP/kg DM for T1, and 115 g CP/kg DM for T2 and T3 (Tables 2 and 3). Barros et al. (2017) reported MUN values as low as 5.97 mg/dl with diets of 118 g CP/kg in high yielding, late lactation cows, with a decrease in milk yields and MUN values when changing CP content of rations below 144 g CP/kgDM.

As shown in Table 4 the significantly higher (P<0.01) silage and feeding costs in T3 (BKO) were due to a lower forage yield compared to T1 (BLY), and to T2 the mixture of silages. However, these differences disappear for all the other variables of the economic analyses given the slight but non significant higher milk production in T3 (BKO).

Profit margins in the experiment were similar to reports by Celis-Alvarez et al. (2016) and Burbano-Muñoz et al. (2018) when evaluating the inclusion of common oat silage for dairy cows in SSDS, but higher than reports by Prospero-Bernal et al. (2017) when maize silage is implemented.

In conclusion, both barley and black oat silages are viable alternatives for the feeding strategies for milking cows in small-scale dairy systems, but BLY represents lower costs and higher economic margins.

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**Table 1. Chemical composition of silage barley (BLY), silage Black Oat (BKO), pastures and concentrate**

| | BLY | BKO | Pasture | | | Concentrate |
|---|---|---|---|---|---|---|
| | | | PI[a] | PII[a] | PIII[a] | |
| Dry Matter (g/kg DM) | 226 | 209 | 246 | 276 | 217 | 930 |
| Organic Matter (g/kg DM) | 788 | 857 | 872 | 865 | 872 | 857 |
| Crude Protein (g/kg DM) | 66.0 | 70 | 174 | 178 | 217 | 195 |
| Neutral Detergent Fiber (g/kg DM) | 568 | 554 | 425 | 483 | 465 | 196 |
| Acid Detergent Fiber (g/kg DM) | 420 | 376 | 211 | 337 | 310 | 91 |
| pH | 4.0 | 3.8 | - | - | - | - |
| Starch (g/kg DM) | 167 | 100 | - | - | - | 471 |
| IVOMD[b] (g/kg DM) | 560.2 | 683.4 | 806.3 | 770.2 | 813.6 | 872.9 |
| eME[c] (MJ/kg DM) | 8.3 | 10.2 | 12.1 | 11.6 | 12.3 | 13.2 |

**Note:** [a] Experimental Periods, I,II and III.

[b] *In vitro* Organic Matter Digestibility

[c] Estimated Metabolizable Energy.

**Table 2. Dry matter intakes (DMI) (kg DM/cow/day) in treatments T1 (100% BLY[a]), T2 (50%BLY+50%BKO[b]) and T3 (100% BKO)**

| | Treatments | | | SEM[c] | Significance |
|---|---|---|---|---|---|
| | T1 | T2 | T3 | | |
| Concentrate | 4.6 | 4.6 | 4.6 | 0.00 | NS |
| Silage | 8.2*b* | 8.3*b* | 8.9*a* | 0.14 | ** |
| Pasture | 1.7*a* | 0.4*b* | 0.5*b* | 0.26 | *** |
| DMI | 14.5*a* | 13.4*b* | 14.0*a* | 0.26 | ** |

**Note:** Means within a row not sharing a lowercased italic letter differ statistically ** (P<0.01); *** (P<0.001).

[c] Standard Error of the Mean

**Table 3. Animal variables for treatments T1 (100% BLY[a]), T2 (50%BLY+50%BKO[b]) and T3 (100% BKO)**

| | Treatments | | | SEM[d] | Significance |
|---|---|---|---|---|---|
| | T1[a] | T2[b] | T2[c] | | |
| Milk yield (kg/cow/d) | 15.0 | 14.7 | 15.0 | 0.36 | NS |
| LW [e] (kg) | 484 | 488 | 485 | 3.41 | NS |
| BCS [f] | 2.4 | 2.4 | 2.4 | 0.00 | NS |
| Milk fat (g/kg) | 28.8 | 28.9 | 29.0 | 0.54 | NS |
| Milk protein (g/kg) | 30.3 | 30.6 | 30.5 | 0.14 | NS |
| Lactose (g/kg) | 43.4*a* | 44.3*b* | 44.3*b* | 0.30 | * |
| MUN[g] (mg/dl) | 7.6 | 7.2 | 6.6 | 0.50 | NS |

**Note:** Means within a column not sharing a lowercased italic letter differ significantly statistically (P<0.05); [ns] (P>0.05); * (P<0.05)

[a] 100% Barley silage,

[b] 50% Barley silage + 50% black oat silage

[c] 100% Black oat silage

[d] Standard Error of the Mean

[e] Live weight

[f] Body Condition Score (1-5)

[g] Milk Urea Nitrogen.

**Table 4. Economic analysis (USD\$[e]) for treatments T1 (100% BLY[a]), T2 (50%BLY+50%BKO[b]) and T3 (100% BKO)**

| | Treatments | | | SEM[d] | Significance |
|---|---|---|---|---|---|
| | T1[a] | T2[b] | T3[c] | | |
| Feeding costs | | | | | |
| Commercial concentrate (USD\$) | 20.40 | 20.40 | 20.40 | 0.000 | NS |
| Pasture (USD\$) | 1.64 | 1.64 | 1.64 | 0.000 | NS |
| Silage(USD\$) | 18.42*b* | 18.59*b* | 20.09*a* | 0.340 | ** |
| Total feeding costs (USD\$) | 40.46*b* | 40.64*b* | 42.14*a* | 0.340 | ** |
| Incomes | | | | | |
| Total milk yield (kg) | 205.90 | 206.480 | 214.230 | 4.78 | NS |
| Feeding costs (USD\$/ kg de milk) | 0.213 | 0.207 | 0.214 | 0.008 | NS |
| Selling price (USD\$/kg de milk) | 0.300 | 0.300 | 0.300 | 0.000 | NS |
| Income from milk sales (USD\$) | 61.32 | 61.51 | 63.80 | 1.425 | NS |
| Total margin over feed costs (USD\$) | 20.86 | 20.86 | 21.68 | 1.620 | NS |
| Margin over kg milk (USD\$/kg) | 0.08 | 0.09 | 0.08 | 0.008 | NS |
| Margin over feed costs (USD\$/cow/day) | 1.49 | 1.49 | 1.55 | 0.110 | NS |
| Cost / benefit ratio (USD\$/kg) | 0.082 | 0.081 | 0.081 | 0.002 | NS |

**Note:** Means within a column not sharing a lowercased italic letter differ significantly statistically NS (P>0.05); ** (P<0.01)

[a] 100% Barley silage,

[b] 50% Barley silage + 50% black oat silage

[c] 100% Black oat silage

[d] Standard Error of the Mean

[e] United States Dollars