Influence of Ensiling Additives on Silage Quality of Several Oat Cultivars

Yungui Yang[1], Ning Li[1], Chaoge Jin[1], Yafei Li[1], Wei Li[1], Yanyan Lin[1], Lu Zhao[1], Xuemei Yang[1], Ting Guo[1], David B. Hannaway[2,*]

[1]College of Grassland Agriculture, Northwest A & F University, Yangling, Shaanxi, China

[2]Crop & Soil Science Department, Oregon State University, Corvallis, Oregon, USA.

Abstract

Oats are an important forage and feed crop. However, oats have lower sugar content, protein, and moisture, and higher crude fiber than corn, making them more difficult to ensile. Although the use of additives in the ensiling process may improve silage quality, few studies have evaluated the influence of additives on oat silage quality. The objective of this experiment was to evaluate different additives for their ability to increase the silage quality of several commonly grown oat cultivars. Oat cultivars Dancer, Baiyan 6, and Shadow were treated with *Lactobacillus* (5 mg kg^{-1}), formic acid (5 ml kg^{-1}), sucrose (20 g L^{-1}), and cellulose (100 mg kg^{-1}). *Lactobacillus* and sucrose reduced silage pH and ammonia N, and increased lactic acid content. *Lactobacillus* treated silage also had the highest crude protein level and sucrose was effective in reducing crude fiber content. 'Baiyan 6' had the highest quality index value due to significantly higher crude fat content. ADD cost and recommendations .“Based on these results, both *Lactobacillus* and sucrose can be recommended as additives to increase oat silage quality.

Keywords

Oat Silage; Silage Additives; Oat Cultivars; Nutritional Value; Silage Quality.

1. Introduction

Oat forage has a high livestock feeding value and is oats are often grown in northern regions of China, especially in cold, high elevation areas. Most frequently, oats are grown for hay, but this typically leads to lower nutritional quality than can be obtained through ensiling due to weather conditions that are not conducive to curing hay. Compared with corn grown for silage, however, water soluble carbohydrates, protein, and moisture content of pre-ensiled oats are lower, and crude fiber content is higher, so making high quality oat silage is often difficult (Li, 2008). Readily fermentable carbohydrates, enzymes, and bacterial additives can improve silage quality. This study evaluated several additives with respect to their ability to improve oat silage quality of several commonly grown oat cultivars.

2. Materials and Methods

2.1 Location

Field plots were established at the experiment station of the Grassland Sciences program of the College of Animal Science and Technology of Northwest Agriculture & Forestry University. The location is north of the Qinling mountains and west of the Weihe plain; north latitude 34°21', longitude 108°10', 454.8 m above sea level. Mean annual temperature is 13.7 ℃, average annual rainfall is 622 mm, and the frost-free period ranges from 200 to 220 days. The climate is classified as a warm temperate, semi-humid zone.

2.2 Field planting

Three oat cultivars (Dancer, Baiyan 6, and Shadow) were arranged within a randomized complete block design with three replicates. Plots were 3 m by 5 m. Seeds were drilled on March 20th at a rate of 120 kg hm^{-2} in rows 20 cm apart, resulting in 15 rows per plot. The experimental area was surrounded by a 0.5 m oat border, with each cultivar surrounding its plot area.

2.3 Forage harvest timing and ensiling treatments

Plants were harvested on June 15th, 87 days after planting. They had reached the milk stage of development. Following hand chopping to 2-3 cm, chopped fresh forage was subjected to one of four additives or no additive (CK): (1) 5 mg kg^{-1} *Lactobacillus*, (2) 5 ml kg^{-1} formic acid, (3) 20 g L^{-1} sucrose, or (4) 100 mg kg^{-1} of cellulase. All additives were obtained from Wang Biological Technology (Nanjing) Co., Ltd. Ensiling containers were 1 L plastic bottles (10 cm diameter, 15 cm height, and 0.3 cm wall thickness). Each container was packed with 800-1000 g of oat forage, compressed to a density of 800-1000 kg m^{-3}. With 4 additives plus the check, each replicated 3 times, there were 15 containers for each of the 3 cultivars, resulting in a total of 45 silage bottles.

2.4 Analyses

2.4.1 Nutrient content

Total N was determined on dried samples after complete combustion (Neylon and Jr, 2003) using a Leco CNS 2000 Analyzer (St. Joseph, MI). Percent crude protein (CP) was calculated as percent N multiplied by 6.25. Analyses were conducted for ether extract (EE) (AOAC, 2000), crude fiber (CF) (Weiss&Wyatt, 2004) (Ankom Technology, Fairport, NY), and ash (AOAC, 2000). Nitrogen free extract (NFE) (AOAC, 1990) was calculated.

2.4.2 Silage quality

Sensory evaluation was conducted according to the German Agricultural Society (DIG) silage sensory evaluation standards and rating method (Alexander et al., 1998) which involved comparing the odor, structure, and color. Odor was divided into 5 grades, given 0 to 14 points; structure was divided into 4 grades, given 0 to 2 points; and color was divided into 3 grades, given 0 to 2 points. After adding scores of these three factors, final scores were grouped into 4 grades: excellent (16-20), very good (10-15), good (4-9), and poor (0-3).

Laboratory evaluation included pH, ammonia N, and lactic and acetic acids. pH was determined on 20 g samples into whic 180 ml distilled water was added and stirred with the samples until uniformly mixed. After standing for 24 h, samples were filtered through four layers of qualitative filter paper [General Electric Biotechnology (Hangzhou) Co., Ltd.] and pH was measured using a Mettler Toledo Delta 320 pH meter. Ammonia N (AN) was determined by the phenol hypochlorite colorimetric method (Weatherburn, 1967). The AN/total nitrogen (TN) value is a ratio of ammonia N and total N in silage. Values reflect the degree of protein decomposition in the silage; thus, the higher the ratio, the more amino acid and protein decomposition has occurred, resulting in lower quality silage.

Lactic and acetic acids were determined by gas chromatography with the following instrument conditions: inlet temperature: 220℃, column temperature: 60-120℃ (5℃ min^{-1}), detector temperature: 220 ℃, gas flow rate: 35 ml s^{-1}, hydrogen: 0.05 MPa; air: 0.25 MPa, sample size: 2 μL.

2.4.3 Statistical analyses

All data were initially analyzed with the Microsoft Office Excel 2010 software, and expressed in the form of x±sd. SPSS v. 17.0 (SPSS Inc. Chicago, IL) was used for analysis of variance and Duncan's Multiple Range test was used to compare means declared significant ($P<0.05$ throughout, unless otherwise indicated).

3. Results

3.1 Nutrient content

3.1.1 Crude Protein (CP)

Highest CP content (17.22%) was observed with cultivar Shadow treated with *Lactobacillus* (Table 1).

Lowest CP (14.75%) was observed with the check treatment of ‘Dancer.’ Silage additives significantly increased CP of ‘Dancer’ (Fig. 1), while CP content of ‘Baiyan 6’ and ‘Shadow’ did not change significantly after being treated with the four additives.

Table 1. Effects of four additives (Lactobacillus, formic acid, sucrose, and cellulase) on silage quality of three oat cultivars (Dancer, Baiyan 6, and Shadow) as evaluated by crude protein (CP), ether extract (EE), crude fiber (CF), ash, and nitrogen free extract (NFE) ratio

Cultivar	Additive	CP	EE	CF	Ash	NFE
		--------------- % DM ---------------				
Dancer	CK	14.75±0.67^{c}	2.30±0.22^{b}	34.19±2.44^{a}	9.11±0.40^{a}	39.65±4.88^{b}
	Lactobacillus	16.30±0.26^{ab}	2.61±0.15^{a}	32.84±1.07^{ab}	8.41±0.16^{b}	39.83±1.11^{b}
	Formic acid	16.27±0.16^{ab}	2.56±0.06^{ab}	29.25±0.39^{bc}	8.68±0.25^{ab}	43.24±0.68^{ab}
	Sucrose	15.53±0.27^{bc}	2.70±0.19^{a}	27.21±0.71^{c}	8.08±0.23^{b}	46.47±0.39^{a}
	Cellulase	16.90±0.35^{a}	2.81±0.19^{a}	30.01±0.94^{bc}	8.74±0.12^{ab}	41.55±0.12^{b}
Baiyan 6	CK	16.33±0.33^{ab}	4.86±0.23^{a}	31.36±0.80^{ab}	7.97±0.16^{a}	39.47±0.70^{b}
	Lactobacillus	16.17±0.29^{ab}	4.71±0.37^{a}	30.92±1.09^{ab}	7.96±0.02^{a}	40.24±0.73^{b}
	Formic acid	15.66±1.39^{b}	4.71±0.33^{a}	31.76±2.62^{a}	8.15±0.74^{a}	39.72±1.75^{b}
	Sucrose	15.25±0.31^{b}	4.89±0.30^{a}	27.30±1.77^{b}	7.65±0.11^{a}	44.92±3.58^{a}
	Cellulase	16.86±0.23^{a}	4.80±0.28^{a}	30.62±0.79^{ab}	8.08±0.12^{a}	39.64±1.05^{b}
Shadow	CK	16.00±0.71^{ab}	3.65±0.42^{a}	30.38±1.57^{bc}	9.24±0.34^{c}	40.72±2.13^{b}
	Lactobacillus	17.22±0.56^{a}	3.62±0.09^{a}	28.68±0.59^{cd}	9.09±0.10^{c}	41.39±0.48^{b}
	Formic acid	15.21±0.93^{b}	3.56±0.19^{a}	32.24±0.63^{ab}	9.93±0.45^{bc}	39.06±0.38^{bc}
	Sucrose	15.31±0.49^{b}	3.50±0.04^{a}	27.21±1.32^{d}	8.93±0.12^{c}	45.05±1.60^{a}
	Cellulase	14.97±0.36^{b}	4.00±0.33^{a}	33.31±1.63^{a}	10.75±0.51^{a}	36.96±1.11^{c}

Note: Values followed by different letters in a column are significantly different at the 0.05 probability level.

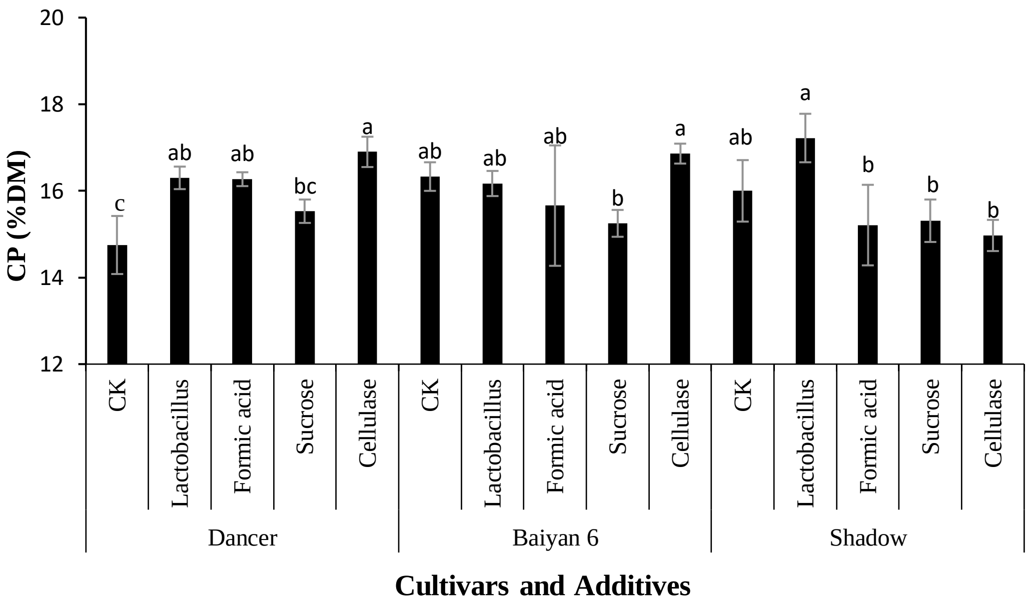

Fig. 1 Percent crude protein (CP) of three oat cultivars (Dancer, Baiyan 6, Shadow) as affected by four additives (Lactobacillus, formic acid, sucrose, and cellulase).

3.1.2 Ether Extract (EE)

Percent EE of 'Baiyan 6' was significantly higher than that of the other two cultivars, with values ranging from 4.71% to 4.89% (Table 1 and Fig. 2). 'Shadow' EE values ranged from 3.50% to 4.00%, while 'Dancer' had the lowest values, from 2.30% to 2.81%. Although additives significantly increased the EE of 'Dancer,' values were still significantly lower than for 'Baiyan 6' and 'Shadow.' No significant differences due to additives were found for percent EE in cultivars Baiyan 6 and Shadow.

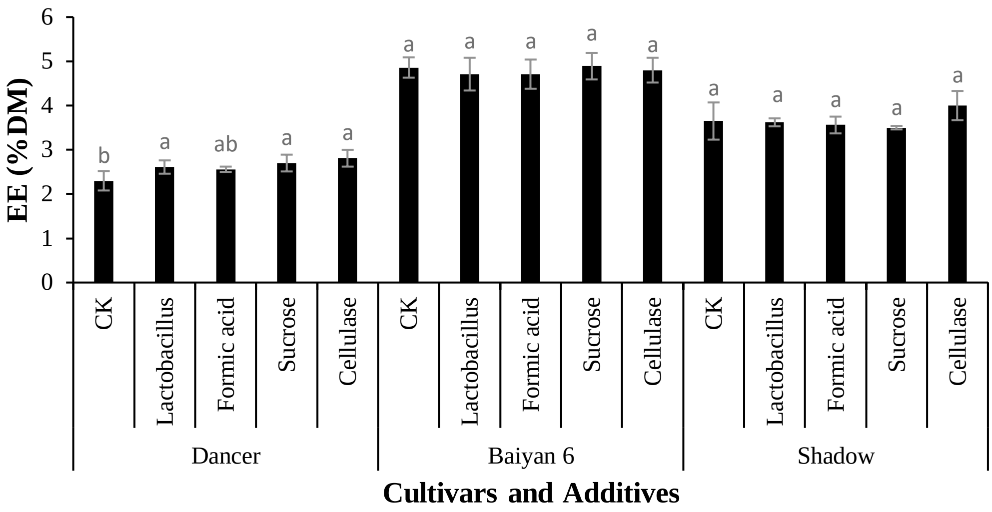

Fig. 2 Percent ether extract (EE) of three oat cultivars (Dancer, Baiyan 6, Shadow) as affected by four additives (Lactobacillus, formic acid, sucrose, and cellulase).

3.1.3 Crude Fiber (CF)

Highest percent CF was found in the CK treatment for 'Dancer' (34.19%, Table 1 and Fig. 3). Significantly lower CF percentages were found with the sucrose treatment (27.21, 27.21, and 27.30 for 'Dancer' 'Bainyan 6,' and 'Shadow,' respectively). No other significant differences due to silage additives were found.

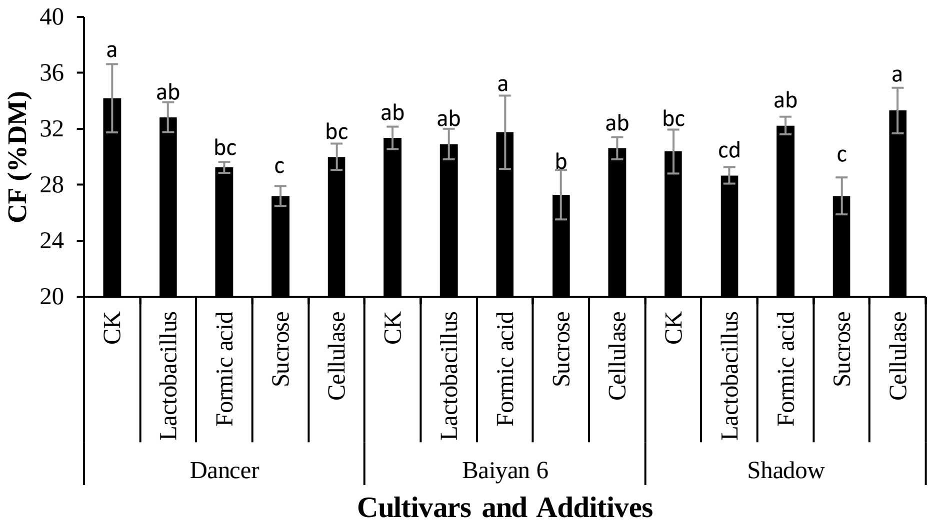

Fig. 3 Percent crude fiber (CF) of three oat cultivars (Dancer, Baiyan 6, and Shadow) as affected by four additives (Lactobacillus, formic acid, sucrose, and cellulase).

3.1.4 Ash

Highest percent ash was found in 'Shadow' treated with cellulase (10.75%, Table 1), significantly higher than other ensiling additives. No treatment differences were observed for 'Bainyan 6'. Percent ash of 'Dancer' was significantly decreased by *Lactobacillus* and sucrose.

3.1.5 Nitrogen Free Extract (NFE)

The NFE for all three cultivars was highest with the sucrose treatment (Table 1), with 'Dancer' having the highest value (46.47%), significantly higher than that of 'Shadow' (40.63%). The cellulase additive resulted in a significantly lower NFE percentage in 'Shadow'.

3.1.6 Main effects of cultivars and additives on oat silage nutritional value

Main effects of cultivars and ensiling additives are shown in Table 2.

Averaged across ensiling additives, percent CP and CF were not significantly different for the three cultivars. Percent EE of ‘Baiyan 6’ was significantly higher than for ‘Shadow,’ which was significantly higher than ‘Dancer’. Percent ash was significantly different for the 3 cultivars, highest for ‘Shadow’ and lowest for ‘Baiyan 6.’ Percent NFE was significantly higher for ‘Dancer,’ and lowest for ‘Shadow’.

Table 2. Main effects of three cultivars (Danser, Baiyan 6, and Shadow) and four additives (Lactobacillus, formic acid, sucrose, and cellulase) on oat silage quality as evaluated by crude protein (CP), ether extract (EE), crude fiber (CF), ash, and nitrogen free extract (NFE) ratio

		CP (%DM)	EE (%DM)	CF (%DM)	Ash (%DM)	NFE (%DM)
		--------------- % DM ---------------				
Cultivar	Dancer	15.95±0.88[a]	2.59±0.22[c]	30.70±3.11[a]	8.60±0.46[b]	42.15±3.24[a]
	Baiyan 6	16.06±0.81[a]	4.79±0.27[a]	30.39±2.43[a]	7.96±0.34[c]	40.80±2.68[ab]
	Shadow	15.74±1.09[a]	3.67±0.28[b]	30.37±2.54[a]	9.59±0.76[a]	40.63±2.99[b]
Additive	CK	15.69±0.88[bc]	3.60±0.93[b]	31.98±2.86[a]	8.77±0.71[bc]	39.95±2.75[b]
	Lactobacillus	16.56±0.64[a]	3.65±0.92[ab]	30.81±1.98[a]	8.49±0.50[cd]	40.49±0.89[b]
	Formic acid	15.71±1.12[bc]	3.61±0.95[ab]	31.08±1.94[a]	8.92±0.91[ab]	40.67±2.17[b]
	Sucrose	15.37±0.40[c]	3.70±0.97[ab]	27.24±1.95[b]	8.22±0.58[d]	45.48±2.11[a]
	Cellulase	16.24±1.02[ab]	3.87±0.89[a]	31.32±1.83[a]	9.19±1.24[a]	39.38±2.14[b]

Note: Values followed by different letters in different cultivars or different additives are significantly different at the 0.05 probability level.

Averaged across cultivars, ensiling additives had significant effects on several nutritional analyses (Table 2). Percent CP was significantly higher with the *Lactobacillus* treatment and lowest with sucrose. Percent EE was significantly higher with the cellulase treatment and significantly lower in the CK. Percent CF was significantly lower with the sucrose treatment. Percent ash was significantly higher with the cellulose treatment and lowest with the sucrose treatment. Percent NFE was significantly higher with the sucrose treatment.

Table 3. Effects of four additives (Lactobacillus, formic acid, sucrose, and cellulase) on silage quality of three oat cultivars (Dancer, Baiyan 6, and Shadow) as evaluated by pH, sensory evaluation, lactic acid (LA), and the ammonia nitrogen (AN) to total nitrogen (TN) value (AN/TN)

Cultivar	Additive	pH	Sensory Evaluation	LA (g kg^{-1} DM)	AN/TN (%)
Dancer	CK	4.38±0.75[a]	17.33±1.53[a]	36.13±4.89[b]	12.64±3.09[a]
	Lactobacillus	3.49±0.29[ab]	19.67±0.58[a]	54.16±3.60[a]	4.53±0.82[b]
	Formic acid	3.36±0.23[b]	17.00±2.00[b]	39.97±2.77[b]	4.64±0.31[b]
	Sucrose	3.05±0.02[b]	19.33±1.15[a]	49.36±3.37[a]	2.34±0.50[b]
	Cellulase	3.26±0.03[b]	16.00±0.58[b]	37.01±8.22[b]	3.05±0.66[b]
Baiyan 6	CK	3.41±0.11[b]	14.00±1.00[b]	35.92±7.08[b]	3.85±0.11[b]
	Lactobacillus	3.07±0.02[c]	12.00±2.65[a]	61.25±4.36[a]	1.95±0.30[b]
	Formic acid	4.04±0.46[a]	11.33±1.15[b]	38.06±7.19[b]	8.97±0.57[a]
	Sucrose	3.39±0.20[b]	15.00±3.00[b]	47.68±3.95[b]	2.72±0.11[b]
	Cellulase	3.39±0.14[b]	14.33±2.52[b]	41.19±2.66[b]	3.74±0.77[b]
Shadow	CK	3.78±0.34[b]	14.33±2.30[b]	20.88±1.92[b]	7.88±1.02[ab]
	Lactobacillus	3.08±0.01[b]	17.00±1.00[a]	49.66±1.12[a]	2.05±0.11[b]
	Formic acid	4.34±0.32[a]	10.00±1.00[b]	19.20±1.38[b]	10.75±1.03[a]
	Sucrose	3.61±0.12[b]	17.33±0.58[b]	19.74±1.93[b]	4.22±0.63[b]
	Cellulase	4.19±0.65[a]	8.67±1.15[b]	18.83±1.89[b]	10.74±2.41[a]

3.2 Silage quality

3.2.1 pH

All additives lowered silage pH of 'Dancer,' while only *Lactobacillus* lowered pH in 'Baiyan 6' (Table 3 and Fig. 4). For 'Shadow,' formic acid and cellulase increased silage pH.

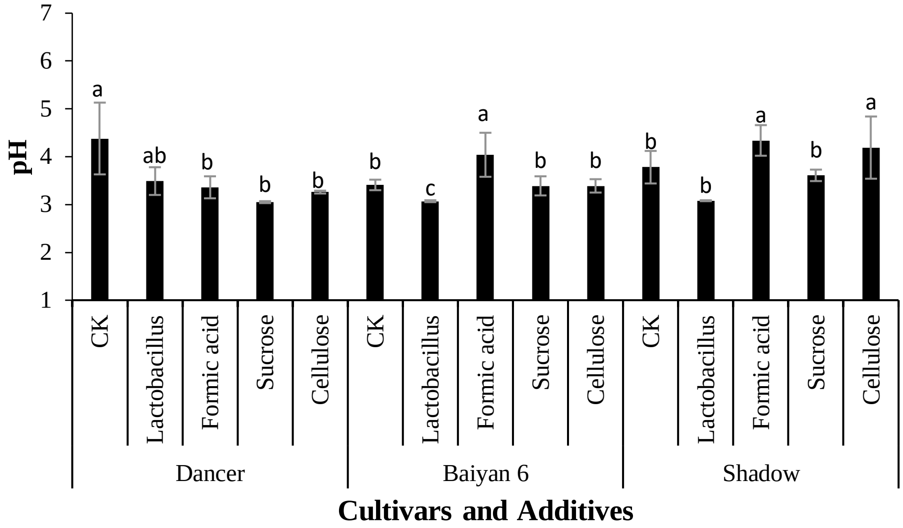

Fig. 4 Effects of four additives (Lactobacillus, formic acid, sucrose, and cellulase) on silage pH of three oat cultivars (Dancer, Baiyan 6, and Shadow).

3.2.2 Sensory evaluation

Highest sensory evaluation values were found with *Lactobacillus* (19.67) and sucrose (19.33) for 'Dancer', and with sucrose for 'Baiyan 6' (15.00) and 'Shadow' (17.33) (Table 3). The lowest sensory evaluation value (8.67) was found in the cellulase treatment of 'Shadow'.

3.2.3 Lactic acid (LA)

Highest percent lactic acid (LA) was found in 'Baiyan 6' when treated with *Lactobacillus* (61.25 g kg^{-1}; Table 3, Fig. 5), with significantly increased values also found in 'Dancer' and 'Shadow'. Sucrose addition significantly increased LA in 'Dancer.'

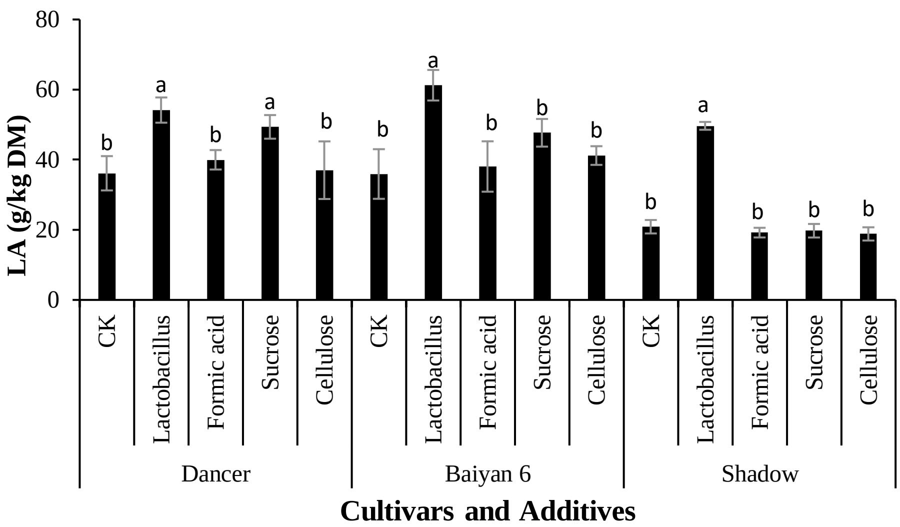

Fig. 5 Effects of four additives (Lactobacillus, formic acid, sucrose, and cellulase) on silage lactic acid concentration of three oat cultivars (Dancer, Baiyan 6, and Shadow).

3.2.4 Ratio of ammonia N to total N (AN/TN)

Silage additives significantly reduced the AN/TN value of 'Dancer', resulted in no significant differences for 'Baiyan 6', and had varied results for 'Shadow' in which adding *Lactobacillus* reduced ammonia N significantly, and sucrose reduced the ratio slightly (Table 3).

3.2.5 Main effects of cultivars and additives on oat silage quality

When averaged across additives, pH was significantly higher in 'Shadow' silage, 3.80 vs 3.51 and 3.46 for 'Dancer' and 'Baiyan 6', respectively (Table 4).

Table 4. Main effects of three cultivars (Dancer, Baiyan 6, and Shadow) and four additives (Lactobacillus, formic acid, sucrose, and cellulase) on oat silage quality as evaluated by pH, sensory evaluation, lactic acid (LA), and the ammonia nitrogen (AN) to total nitrogen (TN) ratio (AN/TN)

		pH	Sensory Evaluation	LA (g kg $^{-1}$ DM)	AN/TN (%)
Cultivar	Dancer	3.51±0.57^{b}	17.87±2.13^{a}	43.32±8.52^{a}	5.44±1.99^{b}
	Baiyan 6	3.46±0.39^{b}	13.33±2.38^{b}	44.82±7.14^{a}	4.24±1.68^{c}
	Shadow	3.80±0.55^{a}	13.47±3.85^{b}	25.66±4.36^{b}	7.13±3.81^{a}
Additive	CK	3.86±0.59^{a}	15.22±2.17^{b}	30.98±8.76^{c}	8.12±2.03^{a}
	Lactobacillus	3.21±0.25^{c}	16.22±3.66^{ab}	55.02±8.06^{a}	2.84±1.68^{b}
	Formic acid	3.91±0.53^{a}	12.78±3.46^{c}	32.41±1.07^{c}	8.12±2.87^{a}
	Sucrose	3.35±0.27^{bc}	17.22±2.49^{a}	38.93±1.47^{b}	3.09±0.92^{b}
	Cellulase	3.61±0.55^{ab}	13.00±3.90^{c}	32.34±1.12^{c}	5.84±1.97^{a}

The sensory evaluation score of 'Dancer' (17.87) was significantly higher than for 'Baiyan 6' (13.33) and 'Shadow' (13.47). LA values of 'Dancer' (43.32) and 'Baiyan 6' (44.82) were significantly higher than for 'Shadow' (25.66). The ratio of ammonia N to total N of 'Baiyan 6' (4.24) was significantly lower than that of 'Dancer' (5.44) and 'Shadow' (7.13).

Averaged across cultivars, the pH value of silage treated with *Lactobacillus* (3.21) was significantly lower than the CK and formic acid treatments, followed by the sucrose treatment (3.35). *Lactobacillus* and sucrose significantly improved sensory evaluation scores compared to the CK. Formic acid and cellulase treatments were significantly lower than the CK. Highest LA (55.02 g kg^{-1}) was found in the *Lactobacillus* treatment, with significant increase also found with the sucrose treatment (38.93 g kg^{-1}). The use of formic acid and cellulase did not significantly increase LA. *Lactobacillus* and sucrose significantly reduced the AN/TN value (2.84 and 3.09 compared with 8.12 for the CK).

4. Discussion

The objective of this experiment was to evaluate the effectiveness of four additives on the quality of three oat cultivars grown for silage.

4.1 Effect of additives on nutrient content

Lactobacillus (5 mg kg^{-1}) was most effective in improving silage quality. Its addition significantly increased the crude protein content and decreased the crude fiber content. Improvement in silage quality of alfalfa and wheat following treatment with *Lactobacillus* was also reported by Ely et al. (1981).

Sucrose (20 g kg^{-1}) was effective in reducing the crude fiber content. Yang Fuyu (Yang, 2004) also reported similar results for sweet clover (*Melilotus alba* Desr.) ensiled with the addition of sucrose.

Although Yang Zhigang (Yang et al., 2004) suggested that adding cellulase would promote cell wall breakdown and thereby provide more fermentable substrates to promote fermentation, cellulase addition (100 mg kg^{-1}) in this study did not significantly change crude fiber or crude protein but cellulase addition did significantly increase ether extract and ash content. This difference in results may be due to cellulose is inactivated during enzymatic hydrolysis.

4.2 Effect of additives on laboratory and sensory quality evaluation

Laboratory evaluation

Lactobacillus and sucrose significantly reduced the pH and AN/TN value of oat silage, and significantly increased lactic acid content.

Numerous previous studies (Cai et al., 1994; Cai et al., 1997; Sanderson et al. 1993; Weinberg ZG et al., 1993) have shown that the addition of *Lactobacillus* can improve the silage fermentation process due to suboptimal amounts of *Lactobacillus* occurring naturally. When *Lactobacillus* is added, the pH of the ensiled forage is rapidly reduced due to the production of higher amounts of lactic acid. In addition, the hydrolysis of proteins [by other microorganisms] is inhibited in a low pH environment, reducing the production of ammonia N and increasing feed quality and palatability. Our study confirmed that *Lactobacillus* addition significantly decreased the pH and significantly increased the lactic acid content across all cultivars.

Lactobacillus and sucrose significantly reduced the silage AN/TN value. In addition, both *Lactobacillus* and sucrose increased sensory evaluation scores significantly. This is consistent with research on the effects of additives on *Portulaca* reported by Guo Jinmei (Guo et al., 2011; Bai, 2000). In our experiment, formic acid and cellulase addition did not significantly improve silage quality with respect to pH, lactic acid, or the AN/TN value. This is consistent with the results of Chen (2011), Singh et al. (1996), and Jaakkola et al., 1991) ensiling *Portulaca* and water hyacinth (*Eichhornia crassipes* Mart.). This lack of improvement in silage quality from these additives may be because formic acid and cellulase additions can destroy the structure of ensiling materials and thereby decrease silage sensory evaluation and because the experimental materials were different. In addition, cellulase had a strong pertinence, and Yang (2002) noted that only when the selected enzyme preparation was suitable did the enzyme preparation play a more significant role in the substrate.

These results confirmed that *Lactobacillus* and sucrose reduced silage pH and ammonia N, and increased lactic acid content. *Lactobacillus* treated silage also had the highest crude protein level and sucrose was effective in reducing crude fiber content. 'Baiyan 6' had the highest quality index value due to significantly higher crude fat content, It may be due to breed difference.

Sensory evaluation was improved when *Lactobacillus* and sucrose were added.

4.3 Average additive differences

Averaged across cultivars, ensiling additives had significant effects on several nutritional analyses. Percent CP was significantly higher with the *Lactobacillus* treatment and lowest with sucrose. Percent EE was significantly higher with the cellulase treatment and significantly lower in the CK. Percent CF was significantly lower with the sucrose treatment. Percent ash was significantly higher with the cellulose treatment and lowest with the sucrose treatment. Percent NFE was significantly higher with the sucrose treatment.

5. Conclusion

Compared with untreated oat silage, treatment with *Lactobacillus*, formic acid, sucrose, and cellulase resulted in various quality changes. *Lactobacillus* increased crude protein, sucrose reduced crude fiber,and cellulase increased ether extract and ash. *Lactobacillus* and sucrose were more effective in reducing the pH and AN/TN and in increasing lactic acid content. Therefore, both *Lactobacillus* and sucrose can be recommended as additives to increase oat silage quality. 'Baiyan 6' was the highest ranked cultivar for both nutrient analyses and sensory silage quality evaluation in Shannxi provence.

Acknowledgments

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