Ensiled High Moisture Barley and Wheat in Nursery Pig Diets

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The primary objective of this research was to investigate the nutritional value of high moisture (HM) barley and wheat ensiled with lactic acid bacteria (LAB) with or without the addition of feed enzymes for nursery pigs. Overall, the results showed that HM barley and wheat can be successfully ensiled with LAB and feed enzymes, and the resulting product was successfully incorporated into dry feed. Piglets fed diets containing ensiled HM grains had improved growth. This effect was more evident with ensiled wheat than barley.

INTRODUCTION

Harvesting grains at higher moisture increases options during harvest and is especially important when weather conditions are challenging. However, post-harvest drying or conditioning of high moisture (HM) grains before storage can be costly. An alternative method is to ferment the grains with bacteria and store them under anaerobic conditions.

The weaning period contributes to losses in profit for swine producers, as it is common for pigs to go off feed. This may lead to depressed growth, increased occurrences of enteric diseases and higher mortality. Previously, in-feed antibiotics (antibiotic growth-promotants, AGP) were used to ameliorate the post-weaning growth lag and enteric diseases. However, their use has been associated with the development of antibiotic resistance in human pathogens and environmental pollution. Thus, the use of AGP has been banned in several jurisdictions and, restrictions have been placed on AGP use in Canada and the United States.

Table 1. Treatment structure for the research

Treatment	Grain	Inoculant1	Enzyme2
1	Barley	Control	No
2	Barley	Control	Yes
3	Barley	Homofermentative	No
4	Barley	Homofermentative	Yes
5	Barley	Heterofermentative	No
6	Barley	Heterofermentative	Yes
7	Wheat	Control	No
8	Wheat	Control	Yes
9	Wheat	Homofermentative	No
10	Wheat	Homofermentative	Yes
11	Wheat	Heterofermentative	No
12	Wheat	Heterofermentative	Yes

1Inoculant: control = no bacterial inoculant; HO = homofermentative lactic acid bacteria (L. plantarium; Biosil); HE = heterofermentative lactic acid bacteria (L. buchneri; Lalsil).
2 Enzyme: Yes = multi-carbohydrases and phytase inclusion (SuperzymeTM plus); No = no enzyme included.

Diets containing fermented feed ingredients could be a suitable substitute for AGP, as these feeds could provide health benefits and promote growth by improving digestibility, palatability and providing anti-microbial organic acids.

Feed or ingredients can be ensiled with lactic acid bacteria (LAB), which ultimately results in enrichment of feeds with organic acids and short chain fatty acids. Numerous studies have been reported on the ensiling of HM maize with LAB and its feeding value. However, there is limited information on the nutritional value of feeding LAB ensiled HM wheat and barley, to weanling pigs. Therefore, the overall objective of this research project was to investigate the nutritional value of ensiled HM barley and wheat for weaned piglets.

MATERIALS AND METHODS

Ensiling protocol

The initial approach was to establish a small scale ensiling methodology using homo-fermentative (HO; ferment carbohydrates to exclusively lactic acid) or hetero-fermentative (HE; ferment carbohydrates to numerous by-products including lactic acid and ethanol) LAB inoculation. Wheat and barley were ground to pass through a 3-mm sieve and subsequently mixed with de-mineralized water for 10 min in order to achieve 27% moisture content (HM grains) before adding the LAB inoculants and enzymes. The fermentation treatment followed a 2 × 3 × 2 factorial design with grain type (barley and wheat), bacteria inoculant (no addition, HO and HE) and enzyme additives (no enzyme and SuperzymeTM Plus) as main effects (Table 1). The HO inoculant was L. plantarum DSMZ 8862 and DSMZ 8866 (Bio-Sil®; Technology and Product Development GmbH, Wuthenow, Germany) and was added at 6 x 105 CFU/g of fresh grains. The HE inoculant was

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L. buchneri NCIMB 40788 (Lalsil®Fresh; Lallemand Inc., Montreal, Canada), added at 6 x 105 CFU/g fresh grain. The multi-enzyme formulation (SuperzymeTM plus, Canadian Bio-systems, Calgary, Canada) containing both carbohydrases and phytase was added at the rate of 0.5g/kg dry grain. Each treatment was prepared in 1.5 L glass jars with 4 replicates and 4 sampling time points (day 6,15, 55 and 97) for analysis of fermentation parameters (short-chain fatty acids, ethanol, and ammonia), nutrient content and microbial count.

Growth Performance Trial

For the growth performance trial, reconstituted grains were ensiled by adding the bacterial inoculants and enzymes. The resulting mixture was tightly packed into barrels, sealed and stored for 90 days at room temperature. After 9 months of storage, the fermented grains were used to produce experimental nursery diets for the trial. This trial used the same 12 treatments described above, fed to 96 pens of 5 pigs/pen (weaned at 21 days of age, n=480) for 28 days. Pigs were allocated to pens based on body weight, regardless of sex. Each pen housed 5 pigs from day 0 to day 4. On day 4 of the trial, the average pig from each non-enzyme treatment pen (50% of treatments) was removed and euthanized to collect intestinal tissue and digesta samples to investigate parameters associated with gut health. Pigs were also removed from the other treatment pens so that from day 4 to day 28, all pigs were housed in groups of 4. Pigs and feeders were weighed weekly until day 28 to calculate average daily feed intake (ADFI), average daily gain (ADG) and gain to feed ratios (G: F) for each pen.

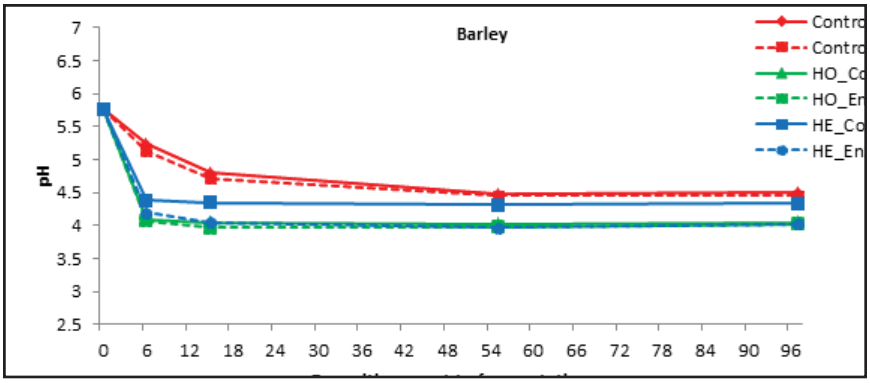

Figure 1a. pH of HM barley samples ensiled with lactic acid bacteria and without or with enzymes up to day 97 of fermentation. Inoculant: Control = no bacterial inoculant; HO = homo-fermentative lactic acid bacteria (L. plantarium; Biosil); HE = hetero-fermentative lactic acid bacteria (L. buchneri; Lalsil). Enzyme: Yes = multi-carbohydrases and phytase inclusion (Superzyme); No = no enzyme included

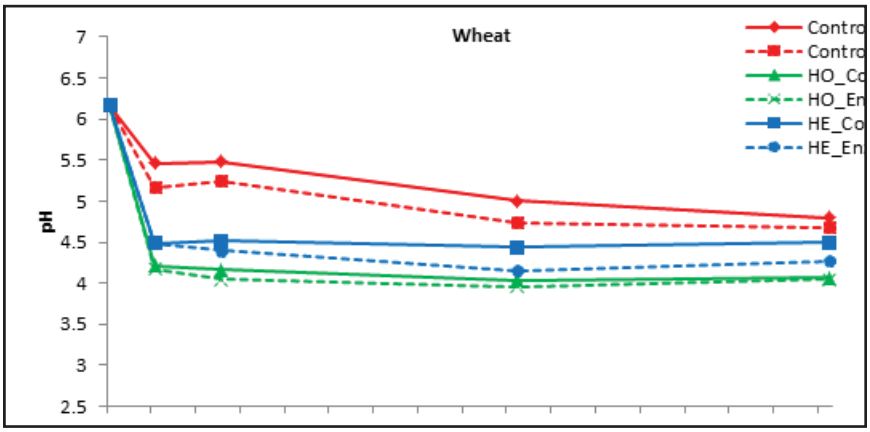

Figure 1b. pH of HM wheat samples ensiled with lactic acid bacteria and without or with enzymes up to day 97 of fermentation. Inoculant: Control = no bacterial inoculant; HO = homo-fermentative lactic acid bacteria (L. plantarium; Biosil); HE = hetero-fermentative lactic acid bacteria (L. buchneri; Lalsil). Enzyme: Yes = multi-carbohydrases and phytase inclusion (Superzyme); No = no enzyme included.

RESULTS AND DISCUSSION

The pH of the ensiled grains was measured to indicate microbial activity and preservation success during the ensiling. There was a 3-way interaction ($P < 0.05$) for grain, inoculant and enzymes on pH for the various sampling times (data not shown).The addition of LAB inoculants to the HM grains led to a pH decline below 4.5 after six days of storage (Figure 1 a and b); however, no further significant decreases were observed for the subsequent days of storage. The effect of inoculant on pH was more evident with wheat than barley ($P < 0.05$), resulting in a 2-way interaction for grain type and inoculant. Further, enzyme addition to the ensiled grains resulted in a decreased ($P < 0.05$) in pH compared to the when enzymes were not added to the mixture.

Piglets fed HM wheat had greater overall ADG and ADFI but reduced G:F than those fed HM barley (Table 2). Bacterial inoculation, regardless of type, increased final BW and overall ADG (0.22 vs 0.25 kg/d) and ADFI (0.32 vs 0.37 kg/d; $P<0.01$) but had no effect on G:F ($P=0.10$). The effect of inoculant was more evident in wheat than barley-based diets, resulting in a 2-way interaction for grain type by inoculant for final BW, day 0 to 28 ADG and ADFI. However, the addition of enzymes during the ensiling had no effect on piglet performance. Treatments had no effect on villi height, villi width or the villi: crypt ratio in the jejunum of pigs (data not shown).

CONCLUSION

The present research shows that HM grains can be successfully ensiled with LAB and enzymes and that this process had a significant effect on the concentrations of nutrients and fermentation characteristics. Further, ensiling the HM grains with LAB inoculant improved nursery pig growth performance, and the effects were more evident with wheat. However, the addition of enzymes during the ensiling process had no effect on growth performance. Finally, we have shown that ensiled HM grains can be successfully incorporated into standard dry feeding system. Therefore, producers interested in the yield and flexibility of harvesting HM grains for swine feeding may benefit from this approach. Likewise, an enterprise could produce a specialty fermented grain product and market to feed companies or swine producers.

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Table 1. Growth performance of wenaling pigs (21 2 days) fed diets containing lactic acid bacteria and ensiled wheat or barley with or without enzymes[a]

	Grain		Enzyme[1]			Inoculant[2]				P values (if no value P > 0.10)[3]	
Item	Barley	Wheat	No	Yes	SEM[4]	Control	HO	HE	SEM[5]	G	I
BW, kg											
d 0	5.98	5.97	5.98	5.96	0.190	5.97	5.97	5.97	0.190		
d 7	6.01	6.13	6.08	6.06	0.200	6.02	6.13	6.06	0.200	0.009	
d 14	7.17	7.23	7.09	7.22	0.250	7.08	7.23	7.30	0.250		0.038
d 21[6,7]	9.16	9.32	9.18	9.30	0.340	8.97	9.32	9.44	0.350		0.003
d 28[6]	12.50	12.70	12.60	12.70	0.430	12.20	12.70	12.90	0.440		0.002
ADG, kg/d											
d 0-7	0.01	0.02	0.02	0.01	0.004	0.01	0.02	0.01	0.005	0.006	0.080
d 0-28[6]	0.23	0.24	0.24	0.24	0.010	0.22	0.24	0.25	0.010		0.002
ADFI, kg/d											
d 0-78	0.08	0.09	0.08	0.07	0.010	0.07	0.08	0.09	0.010	0.025	0.054
d 0-28[6]	0.34	0.36	0.35	0.35	0.020	0.32	0.35	0.37	0.020	0.003	<.0001
G: F											
d 0-7	0.03	0.23	0.16	0.09	0.060	0.00	0.15	0.22	0.070	0.014	0.072
d 0-28[9,10]	0.70	0.67	0.69	0.68	0.010	0.69	0.69	0.67	0.010	0.007	0.096

[a] The statistical model examined the main effect of grain type (G), inoculant type (I) and enzyme type (E) and their interactions. Significance, P < 0.05; trend P < 0.10

[1] Enzyme: Yes = multi carbohydrases and phytase inclusion (Superzyme); No = no enzyme included.

[2] Inoculant: Control = no bacterial inoculant; HO = homo-fermentative lactic acid bacteria (L. plantarium; Biosil); HE = hetero-fermentative lactic acid bacteria (L. buchneri; Lalsil).

[3] Enzyme (P > 0.10)

[4] SEM, standard error of treatment means for the main effect of grain type and enzymes

[5] SEM, standard error of treatment means for the main effect of inoculant.

[6] Grain × Inoculant (P < 0.05)

[7] Grain × Enzyme (P < 0.05)

[8] Grain × Enzyme (P < 0.10)

[9] Grain × Inoculant × Enzyme (P < 0.10)

[10] Inoculant × Enzyme (P < 0.10)

[11] Grain × Inoculant (P < 0.10)

[12] Inoculant × Enzyme (P < 0.05)