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An Evaluation of Nutrition Strategies to Lower Pig Starter Feed Costs

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Abstract

Four hundred-ten pigs (weaning wt. = 12.1 lb.) were used in four experiments to evaluate the impact of four progressively lower cost pig starter formulations on pig performance during an initial 7-14 day transition, and for an overall 28-post-weaning feeding period. The four experimental preparations: **Diet 1)** 22% dried whey (DW), 7.5% lactose (L), and 6% spray dried animal plasma (SDAP), **Diet 2)** 22% DW, 7.5% L, 2% SDAP, 2% soy protein concentrate (SPC), and 2% spray dried blood meal (SDBM), **Diet 3)** 29% DW and 4.5% SDAP, **Diet 4)** 29% DW, 1.5% SDAP, 2% SPC, and 1% SDBM were fed in corn-, hull-less waxy barley-, hull-less oats- and HRS wheat-based diets in separate experiments and compared to a corn control diet containing 22% DW, 7.5% L and 6% SDAP. Formulations containing either 4.5 or 6% SDAP minimized weaning lag during the initial 0-14 day period following weaning when corn and hull-less waxy barley served as the grain bases. However, compensating growth during the 14-28 day period by pigs fed the lowest cost diet 4 resulted in overall feed cost savings of 15.5 and 10.6% respectively, for corn and hull-less waxy barley fed pigs. When the experimental formulations were fed with either hull-less oats or HRS wheat the stimulating effect of SDAP on ADG and feed intake were not observed. In the presence of hull-less oats and HRS wheat, early-weaning pig growth without weaning lag was recorded with all of the test formulations. Over the 28-day feeding period, and compared to the corn control diet, feeding the lowest cost Diet 4 lowered feed costs 5.8 and 17.6% respectively, for pigs fed HRS wheat and hull-less oats.

Introduction

When baby pigs are weaned between 14 and 21 days of age nutrient-dense pig starter feed must be provided to insure steady and economical growth without weaning lag. Within the first four weeks after a 21 day weaning, a healthy pig will customarily consume from 27 to 32 pounds of feed and grow an average .7 pound per day. This growth is derived from gains ranging from .30 pound/day during the first week after weaning to gains of 1.10 pounds/day by the end of a four week post-weaning period. Pigs weaned averaging 10 to 13 pounds that grow according to their full genetic potential will nearly triple their weight, weighing 29 – 33 pounds in four weeks, while consuming 1.6 pounds of nutrient-dense feed/pound of gain. Feed consumption during the first 28-days after weaning represents approximately 5% of the feed required to grow a pig from weaning to 250 pounds. While the young, healthy, pig is a very efficient converter of nutrients to body tissue, dietary ingredients required to insure pigs will grow to their full genetic potential are expensive. Exercising a plan for the strategic allocation of nutrient dense ingredients may provide a way to lower pig starter feed cost without compromising weanling pig growth.

Highly digestible feedstuffs such as spray-dried animal plasma (SDAP), soy protein concentrate (SPC), spray-dried blood meal (SDBM), purified lactose (L) and dried whey (DW)] are valuable ingredients in pig starter diets. When supplied in proper proportions they stimulate feed intake, daily gain and minimize post-weaning lag (Stoner et al., 1990, Hansen et al., 1993, Kats et al., 1994 and de Rodas et al., 1995). The first objective of this nutrition management investigation was to evaluate nutrient replacement strategies to determine if feed intake and pig growth could be maintained while lowering the cost of production. The second objective was to evaluate pig response and efficacy when the experimental protein and lactose formulations were prepared with either corn, hull-less oats, hull-less waxy barley or spring wheat as basal grains.

Materials and Methods

Four experiments were conducted using four hundred-ten pigs in which corn, hull-less waxy barley, hull-less oats, or HRS wheat were used as grain-bases. A corn-based control diet containing 22% dried whey (DW), 7.5% lactose (L) and 6% spray-dried animal plasma (SDAP), was compared to the following progressively less expensive phase-1 diets: **Diet 1)** 22% DW, 7.5% L, and 6% SDAP, **Diet 2)** 22% DW, 7.5% L, 2% SDAP, 2% SPC, and 2% SDBM, **Diet 3)** 29% DW and 4.5% SDAP, **Diet 4)** 29% DW, 1.5% SDAP, 2% SPC, and 1% SDBM. Weaning transition test diets fed during Phase-1 (0-7 days post-weaning), were reduced significantly in Phase-2 (7-14 days post-weaning) diets, and were removed entirely in a common Phase-3 diet that was fed across all treatment groups during days 14-28 post-weaning. The total feeding period was 28 days. In addition to the lactose and protein test ingredients, all phase-1 diets contained 10% menhaden fish meal and 13% soybean meal. Pig starter diets with each of the grain bases were prepared according to the dietary specifications shown in Table 1 for Phases 1, 2 and 3. Diet cost per ton for each of the three phases and grain bases are shown in Table 2.

Pigs in the study were weaned at 21 days of age, vaccinated with a 3-way multivalent vaccine (A. pleuropneumoniae, H. parasuis and erysipelas) and randomly allotted to four replicates per dietary treatment. Pigs and feed were weighed on 7d, 14d, 21d, and 28d after weaning. Weekly pig performance is shown Tables 3,4,5 and 6 for the test ingredients fed in corn, hull-less waxy barley, hull-less oat, or HRS wheat grain-bases.

Results and Discussion

Corn-Base Pig Starter (Experiment 1, Table 3)

Phase 1 (Transition Diet 0-7 Days)

Pigs with an average starting weight of 13.1 pounds were fed the progressively lower cost transition test diets during week one after weaning. Numerical differences were observed for ADG, but were not different statistically. Total feed consumption and ADFI were greater (P=.03) when either 4.5 or 6% animal plasma was fed in the corn-based starter. Pig gains paralleled feed intake which was numerically higher for pigs that received 4.5 and 6% animal plasma, however, differences in gain between feeding animal plasma alone versus feeding the tested protein combinations (Diets 2 and 4) did not differ. Feed efficiency (G:F) was greatest (P=.07) when lactose was included in the diet.

Phase 2 (Transition Diet 7-14 Days)

Phase-2 gain and ADG were consistent with growth observed in the first phase and was greatest for those pigs receiving Diets 1 and 3 which were formulated with either 4.5 or 6% animal plasma. Feed intake, G:F, and feed cost/pound of gain differed numerically, however, the differences observed were not significant.

Phase 3 (Common Diet 14-28 Days)

Subsequent pig performance following weaning transition diets fed in Phases 1 and 2 differed numerically among the criteria measured but the differences were not significant. Pigs fed Diet 4, formulated to be the lowest cost transition starter diet, yielded the most favorable feed efficiency (P=.05) and feed cost/pound of gain (P=.06) during the 3rd week post-weaning. While gain in the third phase for pigs fed Diet 4 did not differ from the other test diets, pig growth with Diet 4 lagged behind the other test treatments during the first two weeks post-weaning and then grew numerically faster during the last two weeks when the phase-3 diet was fed, suggesting growth and feed efficiency of a compensating nature.

Combined 28-Day Performance
Pigs receiving a corn-based diet and either 4.5 or 6% plasma consumed more during the Phase-1 transition after weaning and for the 28-day period. No measurable difference in pig performance due to lactose source were recorded, however, feed cost/pound of gain was lower when lactose was derived from dried whey. Pigs receiving transition test Diet 4 (29% dried whey, 1.5% animal plasma, 2% soy protein concentrate, and 1% blood meal) had similar feed consumption and gain efficiency when compared to Diets 1 and 3 that contained the highest levels of animal plasma, but Diet 4 was less expensive to feed (P=.07). Although, 28-day feed cost among pigs fed Diet 4 was 15.5 % less, Diet 4 pigs were also 1.5 pounds lighter.

Based on pig performance resulting from test ingredient comparisons in this corn-based experiment, Diet 1 (22% dried whey, 7.5% lactose, and 6% SD animal plasma) was selected to serve as the corn-based control diet for the hull-less waxy barley-, hull-less oat-, and HR spring wheat-based pig starter experiments.

Hull-less Waxy Barley-Base Pig Starter (Experiment 2, Table 4)
Phase-1 (Transition Diet 0-7 Days)
The average starting weight for pigs fed in this second experiment was 11.7 pounds. No differences were measured when the corn control diet was compared to all diets containing hull-less waxy barley. Differences were observed, however, based on protein and lactose sources within the hull-less waxy barley-based diets. Average daily gain (P=.06) and ADFI (P=.01) were greatest when Diet 3 was fed that contained 4.5% SD animal plasma and lactose derived solely from dried whey. Diets that contained dried whey only were also associated with a lower cost/pound of gain.

Phase-2 (Transition Diet 7-14 Days)
During the second week after weaning, differences between diets were minimal, however, test diets containing SD animal plasma (Diet 1 and 3) had a higher gain to feed ratios (P=.03), but differences in feed cost/pound of gain did not differ.

Phase-3 (Common Diet 14-28 Days)
Pigs receiving the lower cost pig starter formulations in Diets 2 and 4 lagged behind the other treatments during Phases 1 and 2, and then grew numerically faster during weeks 3 and 4 of the 28-day feeding study. This growth recovery response was similar to that observed in the first experiment and is a typical growth response of pigs that start on feed slowly following weaning. As a result of the recovery type growth observed, especially during the 3rd week after weaning, pigs receiving hull-less waxy barley diets grew faster, were more feed (P=.05) and cost (P=.05) efficient than pigs fed the control diet. By the 4th week, stability with respect to pig growth and efficiency was evident among all treatments.

Combined 28-Day Period
For the 28-day feeding period, pigs fed the hull-less waxy barley-base performed equally with pigs receiving the corn control diet. Pigs that received the lowest cost transition Diet 4 (29% dried whey, 1.5% SD animal plasma, 2% soy protein concentrate, and 1% blood meal) lagged behind the other treatments during Phases 1 and 2. Compensating growth among pigs receiving Diet 4 resulted in overall comparable performance across treatments and the lowest cost/pound of gain (P=.003). Feeding the cost reducing

protein and dried whey formulation fed in Diet 4 reduced 28-day feed cost by 10.6% when compared to the corn-based control diet.

Hull-less Oat-Base Pig Starter (Experiment 3, Table 5)

Phase-1 (Transition Diet 0-7 Days)

In the presence of hull-less oats, pigs with an average weaning weight of 11.6 pounds grew similarly regardless of test diet protein or lactose source. There was a numerical trend toward slower growth among pigs fed the corn control diet, however, the difference was not significant. Feed cost/pound of gain favored the hull-less oat-based diets (P=.03). An interaction was measured such that in the presence of hull-less oats pigs fed cost reducing diets 2 and 3 positively influenced total feed intake (P=.03) and ADFI (P=.02).

Phase-2 (Transition Diet 7-14 Days)

In the second week, control pigs that lagged behind pigs receiving naked oats during the first week post-weaning compensated for their slower start and gained faster (P=.04) than pigs receiving naked oat test diets.

Phase-3 (Common Diet 14-28 Days)

Growth and G:F efficiency was similar across treatments during the third week post-weaning. Growth during the fourth week was greater (P=.08) among Diets 3 and 4 that were formulated with 29% dried whey as compared to the other treatments formulated with 22% dried whey and 7.5% lactose during the transition phases.

Combined 28-Day Performance

Pig response to cost lowering protein and lactose treatments during the 28-day post weaning period did not differ with respect to gain and feed intake. Gain to feed efficiency was improved (P=.08) when the dietary lactose source was derived solely from dried whey. Diets 3 and 4, formulated with dried whey as the sole source of lactose, were the most economical diets to feed. Feeding the lowest cost Diet 4, over the 28-day post-weaning period, lowered feed cost 17.6% compared to the control diet.

Hard Red Spring Wheat-Base Pig Starter (Experiment 4, Table 6)

Phase-1 (Transition Diet 0-7 Days)

Weanling pigs with an average weaning weight of 11.9 pounds that received wheat-based formulations consumed more feed during the first week post-weaning (P=.01). Numerical differences were observed for many of the parameters measured with respect to protein and lactose sources but mean differences were not significant. Pig growth without any signs of weaning lag was observed across all treatments during the Phase-1 transition period.

Phase-2 (Transition Diet 7-14 Days)

Steady and consistent growth documented in Phase-1 continued into the second week of the study. All treatments supported similar growth and performance suggesting HRS wheat, in the presence of all of the protein and lactose sources tested, effectively minimizes weaning lag.

Phase-3 (Common Diet 14-28 Days)

In the third week, pigs receiving protein combinations in Diets 2 and 4 consumed more feed (P=.08) than those treatments receiving spray-dried animal plasma in Diets 1 and 3. When corn-fed control pigs were compared to all of the wheat-based experimental diets, they grew numerically faster and consumed significantly more feed (P=.01). During the fourth week, pigs that had received dried whey as the sole source of lactose after weaning and those that received the cost reducing protein combinations in Diet 4 gained at the fastest rate and were the most gain efficient (P=.07).

Combined 28-Day Performance

Over the 28-day post-weaning period pigs that had received the lowest cost wheat-based transition Diet 4 consumed more feed, (P=.01), grew at the fastest rate (P=.01), and had the lowest feed cost/pound of gain (P=.07) when compared to the other transition diet treatments. Feeding wheat-based transition Diet 4 resulted in a 5.8% feed savings and pigs that were 2.3 pounds heavier (P=.01) than pig fed the corn-based control diet.

Discussion

Nutrient-dense diets for early weaned pigs must promote feed intake in the transitional young pig and provide highly digestible amino acids in proper balance. Spray-dried animal plasma has been shown by Gatnau and Zimmerman (1990, 1992), Sohn et al. (1991), and Kats et al. (1994) to be an effective, highly digestible, source of amino acids for weanling pigs. Its presence in the transition diet has been shown by Hansen et al. (1993) and de Rodas et al. (1995) to stimulate feed intake and subsequent ADG during the first 7-14 days post-weaning. Bergstrom (1997) further evaluated spray-dried animal plasma in the diets of pigs weaned at 12 – 14 days of age documenting that high health status SEW pigs responded less to the presence of spray-dried animal plasma in the transition diet than pigs of lower health status.

Pigs in the present study were weaned into an All In/All Out nursery facility that was separated from the farrowing facility but located on the same farmstead. Considering pig response to the experimental transition diets fed with the four different feed grains, including either 4.5 or 6% spray-dried animal plasma stimulated feed intake and ADG when corn and hull-less waxy barley were the basal grains. However, when hull-less oats and HRS wheat were the basal feed grains, the presence of either 4.5 or 6% spray-dried animal plasma did not stimulate feed intake and ADG more than the other less expensive protein combinations and lactose sources formulated into Diets 2 and 4. Based on the pig response in the four experiments conducted, formulations that derived lactose solely from dried whey as compared to a combination of dried whey and purified lactose contributed to improved performance and less expense.

Results of these experiments agree with the findings of other research with respect to corn as the basal feed grain when fed in conjunction with spray-dried animal plasma, dried whey and lactose. However, when higher quality wheat and hull-less oat feed grains are the basal grains in early-weaning transition diets, the magnitude of response from spray-dried animal plasma is diminished and lower cost ingredients can be cost effectively utilized.

Implications

Results of these experiments suggest that lower cost nutrient-dense, high performance, transition pig starter diets can be effectively prepared using reduced levels of spray-dried animal plasma, soy protein concentrate, spray-dried blood meal, and dried whey when high energy hull-less oats and HRS wheat are selected as basal grains. Which nutrient-dense ingredients to use in pig starter formulations will be based largely on availability and current economics.

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Table 1. Experimental Diet Nutrient Specifications For Each Phase.

	Crude Protein	Crude Fat	Crude Fiber	Calcium	Avail. Phos.	Lysine	Tryptophan	Threonine	Meth. + Cyst.	Mcal. ME/lb.	Lysine, g/Mcal ME
Phase 1 (0 - 7 Days)	22.5	8.6	1.9	.80	.60	1.60	.30	1.0	.90	3400	4.70
Phase 2 (7 - 14 Days)	20.4	8.6	2.7	.80	.50	1.33	.27	.92	.75	3400	3.91
Phase 3 (14 - 28 Days)	19.3	7.7	3.5	1.0	.50	1.25	.25	.76	.70	3400	3.67

Table 2. Diet Cost/Ton When Experimental Diets Were Prepared With Each Grain Base.

		Diet 1 22% DW, 7.5% L, 6% SDAP	Diet 2 22% DW, 7.5% L, 2% SDAP, SPC, SDBM	Diet 3 29% DW, 4.5% SDAP	Diet 4 29% DW, 1.5% SDAP 2% SPC, 1% SDBM
Corn	Phase 1 (0 - 7 Days)	618.22	566.43	546.03	499.71
	Phase 2 (7 - 14 Days)	392.91	368.06	370.20	352.31
	Phase 3 (14 - 28 Days)	246.31	246.31	246.31	246.31
Hull-less Waxy Barley	Phase 1 (0 - 7 Days)	612.82	563.12	539.81	493.51
	Phase 2 (7 - 14 Days)	388.40	363.94	362.77	344.54
	Phase 3 (14 - 28 Days)	235.33	235.33	235.33	235.33
Hull-less Oats	Phase 1 (0 - 7 Days)	613.22	562.60	538.93	491.02
	Phase 2 (7 - 14 Days)	390.20	364.43	364.63	345.47
	Phase 3 (14 - 28 Days)	223.90	223.90	223.90	223.90
Hard Red Spring Wheat	Phase 1 (0 - 7 Days)	607.78	556.64	533.26	486.05
	Phase 2 (7 - 14 Days)	374.44	351.05	351.83	333.07
	Phase 3 (14 - 28 Days)	220.49	220.49	220.49	220.49

Table 3. Corn-Base 28-Day Pig Starter Performance.

		Diet 1 22% DW 7.5% L 6% SDAP	Diet 2 22% DW, 7.5% L, 2% SDAP, SPC, SDBM	Diet 3 29% DW, 4.5% SDAP	Diet 4 29% DW, 1.5% SDAP 2% SPC, 1% SDBM.	22% Whey vs 29% Whey	An. Plasma vs Protein Comb	Interaction	S. E.
PHASE 1 (0-7 Days)	Starting Weight, lb.	13.2	12.9	13.3	13.1	-	-	-	-
	Ending Weight, lb.	16.4	15.8	16.4	15.4	-	-	-	-
	Gain, lb.	3.19	2.95	3.10	2.24	NS	NS	NS	0.31
	ADG, lb.	0.46	0.41	0.44	0.33	NS	NS	NS	0.04
	Feed/Head, lb.	3.67	3.48	4.06	3.23	NS	0.03	NS	0.20
	ADFI, lb.	0.52	0.50	0.58	0.46	NS	0.03	NS	0.03
	G : F, lb.	0.87	0.83	0.76	0.71	0.07	NS	NS	0.06
	Feed Cost/lb. of Gain, $$	0.36	0.35	0.36	0.37	NS	NS	NS	0.03
PHASE 2 (7-14 Days)	Starting Weight, lb.	16.4	15.8	16.4	15.4	-	-	-	-
	Ending Weight, lb.	21.2	19.5	21.0	19.5	-	-	-	-
	Gain, lb.	4.80	3.70	4.60	4.10	NS	0.06	NS	0.35
	ADG, lb.	0.69	0.53	0.66	0.59	NS	0.05	NS	0.5
	Feed/Head, lb.	6.71	5.78	6.57	5.62	NS	NS	NS	0.52
	ADFI, lb.	0.96	0.83	0.94	0.80	NS	NS	NS	0.07
	G : F, lb.	0.72	0.64	0.70	0.73	NS	NS	NS	0.08
	Feed Cost/lb. of Gain, $$	0.27	0.30	0.27	0.24	NS	NS	NS	0.04

PHASE 3 (14-21 Days)	Starting Weight, lb.	21.2	19.5	21.0	19.5	-	-	-	-
	Ending Weight, lb.	27.2	24.3	27.1	25.7	-	-	-	-
	Gain, lb.	6.00	4.80	6.10	6.20	NS	NS	NS	0.68
	ADG, lb.	0.86	0.69	0.87	0.89	NS	NS	NS	0.10
	Feed/Head, lb.	10.3	10.0	10.6	9.77	NS	NS	NS	0.98
	ADFI, lb.	1.47	1.43	1.51	1.40	NS	NS	NS	0.14
	G : F, lb.	0.58	0.48	0.58	0.63	0.05	NS	NS	0.04
	Feed Cost/lb. of Gain, $$	0.22	0.27	0.21	0.20	0.06	NS	NS	0.02
PHASE 3 (21-28 Days)	Starting Weight, lb.	27.2	24.3	27.1	25.7	-	-	-	-
	Ending Weight, lb.	34.8	31.2	34.9	33.1	-	-	-	-
	Gain, lb.	7.60	6.90	7.80	7.40	NS	NS	NS	0.35
	ADG, lb.	1.09	0.99	1.11	1.06	NS	NS	NS	0.05
	Feed/Head, lb.	10.8	9.60	10.9	10.4	NS	NS	NS	0.51
	ADFI, lb.	1.54	1.37	1.56	1.49	NS	NS	NS	0.07
	G : F, lb.	0.70	0.72	0.72	0.71	NS	NS	NS	0.05
	Feed Cost/lb. of Gain, $$	0.18	0.17	0.17	0.17	NS	NS	NS	0.06
COMB (0-28 DAYS)	Gain, lb.	21.6	18.4	21.6	20.0	NS	0.03	NS	0.89
	ADG, lb.	0.77	0.66	0.77	0.71	NS	0.03	NS	0.03
	Feed/Head, lb.	31.5	28.9	32.2	29.1	NS	NS	NS	1.61
	ADFI, lb.	1.13	1.03	1.15	1.04	NS	NS	NS	0.05
	G : F, lb.	0.69	0.64	0.67	0.69	NS	NS	0.08	0.02
	Feed Cost/lb.Of Gain, $$	0.23	0.24	0.23	0.21	0.07	NS	0.08	0.01

Table 4. Hull-less Waxy Barley-Base 28-Day Pig Starter Performance.

		Corn Ctrl. 22% DW, 7.5% L, 6% SDAP	Diet 1 22% DW, 7.5% L, 6% SDAP	Diet 2 22% DW, 7.5% L, 2% SDAP, SPC, SDBM	Diet 3 29% DW, 4.5% SDAP	Diet 4 29% W. 1.5% P. 2% S. 1% BM	Corn Ctrl. vs H-Wxy Barley Base	22% Whey vs 29% Whey	An. Plasma vs Protein Comb	Interaction	S. E.
PHASE 1 (0-7 Days)	Starting Weight, lb.	11.8	11.7	11.6	11.8	11.7	-	-	-	-	-
	Ending Weight, lb.	14.0	13.5	13.4	14.4	13.6	-	-	-	-	-
	Gain, lb.	2.20	1.80	1.80	2.60	1.90	NS	NS	NS	NS	0.23
	ADG, lb.	0.31	0.26	0.26	0.37	0.27	NS	0.06	NS	NS	0.03
	Feed/Head, lb.	3.00	3.11	2.67	3.48	2.80	NS	NS	0.01	NS	0.17
	ADFI, lb.	0.43	0.44	0.38	0.50	0.40	NS	NS	0.01	NS	0.03
	G : F, lb.	0.73	0.58	0.67	0.75	0.68	NS	NS	NS	NS	0.05
	Feed Cost/lb. of Gain, $$	0.41	0.46	0.43	0.40	0.37	NS	0.05	NS	NS	0.41
PHASE 2 (7-14 Days)	Starting Weight, lb.	14.0	13.5	13.4	14.4	13.6	-	-	-	-	-
	Ending Weight, lb.	17.7	17.5	16.7	18.5	17.1	-	-	-	-	-
	Gain, lb.	3.70	4.00	3.30	4.10	3.50	NS	NS	NS	NS	0.38
	ADG, lb.	0.53	0.57	0.47	0.59	0.50	NS	NS	NS	NS	0.06
	Feed/Head, lb.	5.48	5.38	5.33	5.21	5.18	NS	NS	NS	NS	0.46
	ADFI, lb.	0.78	0.77	0.76	0.74	0.74	NS	NS	NS	NS	0.07
	G : F, lb.	0.68	0.74	0.62	0.79	0.68	NS	NS	0.03	NS	0.05
	Feed Cost/lb. of Gain, $$	0.30	0.24	0.30	0.25	0.25	NS	NS	NS	NS	0.02

PHASE 3 (14-21 Days)	Starting Weight, lb.	17.7	17.5	16.7	18.5	17.1	-	-	-	-	-
	Ending Weight, lb.	22.5	23.3	22.5	23.9	23.5	-	-	-	-	-
	Gain, lb.	4.80	5.80	5.80	5.40	6.40	0.05	NS	NS	NS	0.42
	ADG, lb.	0.69	0.83	0.83	0.77	0.91	0.05	NS	NS	NS	0.06
	Feed/Head, lb.	8.23	9.34	8.90	8.54	9.20	NS	NS	NS	NS	0.50
	ADFI, lb.	1.18	1.33	1.27	1.22	1.31	NS	NS	NS	NS	0.07
	G : F, lb.	0.58	0.62	0.65	0.63	0.70	0.05	NS	NS	NS	0.03
	Feed Cost/lb. of Gain, $$	0.21	0.19	0.18	0.19	0.17	0.01	NS	NS	NS	0.01
PHASE 4 (21-28 Days)	Starting Weight, lb.	22.5	23.3	22.5	23.9	23.5	-	-	-	-	-
	Ending Weight, lb.	29.2	30.7	29.1	30.2	30.2	-	-	-	-	-
	Gain, lb.	6.70	7.40	6.60	6.30	6.70	NS	NS	NS	NS	0.33
	ADG, lb.	0.96	1.06	0.94	0.90	0.96	NS	NS	NS	NS	0.05
	Feed/Head, lb.	10.1	10.5	10.5	10.2	10.3	NS	NS	NS	NS	0.46
	ADFI, lb.	1.44	1.50	1.50	1.46	1.47	NS	NS	NS	NS	0.07
	G : F, lb.	0.66	0.70	0.63	0.62	0.65	NS	NS	NS	0.08	0.02
	Feed Cost/lb. of Gain, $$	0.19	0.17	0.19	0.19	0.18	NS	NS	NS	NS	0.01
COMB (0-28 DAYS)	Gain, lb.	17.4	19.0	17.5	18.4	18.5	NS	NS	NS	NS	1.02
	ADG, lb.	0.62	0.68	0.63	0.66	0.66	NS	NS	NS	NS	0.04
	Feed/Head, lb.	26.8	28.3	27.4	27.4	27.4	NS	NS	NS	NS	1.43
	ADFI, lb.	0.96	1.01	0.98	0.98	0.98	NS	NS	NS	NS	0.05
	G : F, lb.	0.65	0.67	0.64	0.67	0.67	NS	NS	NS	NS	0.02
	Feed Cost/lb.Of Gain, $$	0.25	0.22	0.23	0.23	0.21	.003	NS	NS	0.01	0.01

Table 5. Hull-less Oat-Base 28-Day Pig Starter Performance.

		Corn Control 22% DW, 7.5% L, 6% SDAP	Diet 1 22% DW 7.5% L 6% SDAP	Diet 2 22% DW, 7.5% L, 2% SDAP, SPC, SDBM	Diet 3 29% DW, 4.5% SDAP	Diet 4 29% W, 1.5% SDA P, 2% SPC, 1% SDBM	Corn Ctrl. vs N-Oat Base	22% Whey vs 29% Whey	An. Plasma vs Protein Comb	Interaction	S. E.
PHASE 1 (0-7 Days)	Starting Weight, lb.	11.6	11.4	11.7	11.6	11.5	-	-	-	-	-
	Ending Weight, lb.	12.7	13.1	13.5	13.6	13.0	-	-	-	-	-
	Gain, lb.	1.14	1.67	1.75	1.96	1.50	NS	NS	NS	NS	0.29
	ADG, lb.	0.16	0.24	0.25	0.28	0.21	NS	NS	NS	NS	0.04
	Feed/Head, lb.	2.36	2.38	2.90	2.56	2.19	NS	NS	NS	0.03	0.18
	ADFI, lb.	0.34	0.34	0.41	0.37	0.31	NS	NS	NS	0.02	0.03
	G : F, lb.	0.49	0.70	0.62	0.76	0.68	NS	NS	NS	NS	0.11
	Feed Cost/lb. of Gain, $$	0.64	0.44	0.48	0.35	0.36	0.03	NS	NS	NS	0.18
PHASE 2 (7-14 Days)	Starting Weight, lb.	12.7	13.1	13.5	13.6	13.0	-	-	-	-	-
	Ending Weight, lb.	17.6	17.1	17.3	17.6	17.2	-	-	-	-	-
	Gain, lb.	4.90	4.04	3.75	4.00	4.17	0.04	NS	NS	NS	0.35
	ADG, lb.	0.70	0.58	0.54	0.57	0.60	0.04	NS	NS	NS	0.05
	Feed/Head, lb.	6.02	5.33	5.31	5.44	5.52	NS	NS	NS	NS	0.45
	ADFI, lb.	0.86	0.76	0.76	0.77	0.79	NS	NS	NS	NS	0.06
	G : F, lb.	0.81	0.77	0.71	0.74	0.76	NS	NS	NS	NS	0.05
	Feed Cost/lb. of Gain, $$	0.24	0.26	0.26	0.25	0.24	NS	NS	NS	NS	0.01

PHASE 3 (14-21 Days)	Starting Weight, lb.	17.6	17.1	17.3	17.6	17.2	-	-	-	-	-
	Ending Weight, lb.	23.3	22.5	22.1	22.6	22.7	-	-	-	-	-
	Gain, lb.	5.71	5.42	4.79	5.00	5.50	NS	NS	NS	NS	0.44
	ADG, lb.	0.81	0.77	0.69	0.71	0.79	NS	NS	NS	NS	0.06
	Feed/Head, lb	8.94	8.42	7.63	7.77	8.74	NS	NS	NS	NS	0.82
	ADFI, lb.	1.28	1.20	1.09	1.11	1.25	NS	NS	NS	NS	0.12
	G : F, lb.	0.64	0.64	0.63	0.64	0.63	NS	NS	NS	NS	0.03
	Feed Cost/lb. of Gain, $$	0.19	0.17	0.18	0.18	0.18	NS	NS	NS	NS	0.19
PHASE 4 (21-28 Days)	Starting Weight, lb.	23.3	22.5	22.1	22.6	22.7	-	-	-	-	-
	Ending Weight, lb.	30.8	29.0	27.7	30.2	30.5	-	-	-	-	-
	Gain, lb.	7.47	6.46	5.58	7.63	7.75	NS	0.08	NS	NS	0.86
	ADG, lb.	1.07	0.92	0.80	1.09	1.11	NS	0.08	NS	NS	0.12
	Feed/Head, lb	12.8	11.2	12.4	12.7	12.1	NS	NS	NS	NS	0.93
	ADFI, lb.	1.83	1.60	1.77	1.81	1.73	NS	NS	NS	NS	0.13
	G : F, lb.	0.58	0.58	0.45	0.60	0.64	NS	0.05	NS	NS	0.05
	Feed Cost/lb. of Gain, $$	0.21	0.20	0.26	0.19	0.18	NS	0.07	NS	NS	0.02
COMB (0-28 DAYS)	Gain, lb.	19.2	17.6	16.0	18.6	19.0	NS	NS	NS	NS	1.45
	ADG, lb.	0.69	0.63	0.57	0.66	0.68	NS	NS	NS	NS	0.05
	Feed/Head, lb.	30.1	27.3	28.2	28.5	28.6	NS	NS	NS	NS	1.80
	ADFI, lb.	1.08	0.98	1.01	1.02	1.02	NS	NS	NS	NS	0.06
	G : F, lb.	0.64	0.64	0.56	0.65	0.66	NS	0.08	NS	NS	0.03
	Feed Cost/lb.Of Gain, $$	0.24	0.23	0.26	0.22	0.20	NS	0.01	NS	0.07	0.24

Table 6. HRS Wheat-Base 28-Day Pig Starter Performance.

		Corn Control 22% DW, 7.5% L, 6% SDAP	Diet 1 22% W. 7.5% L. 6% P.	Diet 2 22% DW, 7.5 % L, 2% SDAP, SPC, SDBM	Diet 3 29% DW 4.5% SDAP	Diet 4 29% DW, 1.5% SDAP, 2% SPC, 1% SDBM	Corn Ctrl. vs Wheat Base	22% Whey vs 29% Whey	An. Plasma vs Protein Comb	Interaction	S. E.
PHASE 1 (0-7 Days)	Starting Weight, lb.	11.9	12.0	11.8	11.8	11.9	-	-	-	-	-
	Ending Weight, lb.	14.4	14.6	14.6	14.8	15.1	-	-	-	-	-
	Gain, lb.	2.50	2.60	2.80	3.00	3.20	NS	NS	NS	NS	0.49
	ADG, lb.	0.36	0.37	0.40	0.43	0.46	NS	NS	NS	NS	0.07
	Feed/Head, lb.	2.72	3.50	3.61	3.11	3.83	0.01	NS	NS	NS	0.24
	ADFI, lb.	0.39	0.50	0.52	0.44	0.55	0.01	NS	NS	NS	0.03
	G : F, lb.	0.92	0.74	0.78	0.96	0.84	NS	NS	NS	NS	0.17
	Feed Cost/lb. of Gain, $$	0.37	0.41	0.37	0.32	0.30	NS	NS	NS	NS	0.05
PHASE 2 (7-14 Days)	Starting Weight, lb.	14.4	14.6	14.6	14.8	15.1	-	-	-	-	-
	Ending Weight, lb.	18.6	18.6	18.8	18.8	19.6	-	-	-	-	-
	Gain, lb.	4.20	4.00	4.20	4.00	4.50	NS	NS	NS	NS	0.59
	ADG, lb.	0.60	0.57	0.60	0.57	0.64	NS	NS	NS	NS	0.08
	Feed/Head, lb.	6.89	6.31	6.22	6.16	7.25	NS	NS	NS	NS	0.40
	ADFI, lb.	0.98	0.90	0.89	0.88	1.04	NS	NS	NS	NS	0.06
	G : F, lb.	0.61	0.63	0.68	0.65	0.62	NS	NS	NS	NS	0.07
	Feed Cost/lb. of Gain, $$	0.34	0.30	0.26	0.29	0.28	NS	NS	NS	NS	0.04

PHASE 3 (14-21 Days)	Starting Weight, lb.	18.6	18.6	18.8	18.8	19.6	-	-	-	-	-
	Ending Weight, lb.	23.2	21.7	22.4	22.2	23.9	-	-	-	-	-
	Gain, lb.	4.60	3.10	3.60	3.40	4.30	NS	NS	NS	NS	0.57
	ADG, lb.	0.66	0.44	0.51	0.49	0.61	NS	NS	NS	NS	0.08
	Feed/Head, lb.	8.05	6.19	6.64	6.47	7.39	0.01	NS	0.08	NS	0.35
	ADFI, lb.	1.15	0.88	0.95	0.92	1.06	0.01	NS	0.08	NS	0.05
	G : F, lb.	0.57	0.50	0.54	0.53	0.58	NS	NS	NS	NS	0.07
	Feed Cost/lb. of Gain, $$	0.24	0.23	0.21	0.21	0.19	NS	NS	NS	NS	0.03
PHASE 4 (21-28 Days)	Starting Weight, lb.	23.2	21.7	22.4	22.2	23.9	-	-	-	-	-
	Ending Weight, lb.	30.6	28.9	30.3	30.2	32.9	-	-	-	-	-
	Gain, lb.	7.40	7.20	7.90	8.00	9.00	NS	0.07	0.08	NS	0.45
	ADG, lb.	1.06	1.03	1.13	1.14	1.29	NS	0.07	0.08	NS	0.06
	Feed/Head, lb.	12.2	11.0	12.0	12.0	13.5	NS	0.05	0.05	NS	0.55
	ADFI, lb.	1.74	1.57	1.71	1.71	1.93	NS	0.04	0.04	NS	0.08
	G : F, lb.	0.61	0.65	0.66	0.67	0.67	NS	NS	NS	NS	0.04
	Feed Cost/lb. of Gain, $$	0.20	0.16	0.17	0.17	0.17	0.02	NS	NS	NS	0.01
COMB (0-28 DAYS)	Gain, lb.	18.7	16.9	18.5	18.3	21.0	NS	0.02	0.01	NS	0.68
	ADG, lb.	0.67	0.60	0.66	0.65	0.75	NS	0.02	0.01	NS	0.02
	Feed/Head, lb.	29.9	27.0	28.5	27.8	32.0	NS	0.04	0.01	NS	0.90
	ADFI, lb.	1.07	0.96	1.02	0.99	1.14	NS	0.03	0.01	NS	0.03
	G : F, lb.	0.63	0.63	0.65	0.66	0.65	NS	NS	NS	NS	0.24
	Feed Cost/lb.Of Gain, $$	0.25	0.24	0.22	0.22	0.21	0.02	0.07	NS	NS	0.01

Using Wheat Screenings, Field Peas, and Canola Seed as Replacements for Corn and Soybean Meal in Diets for Growing-Finishing Swine.

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Abstract
Two performance experiments were conducted with growing-finishing pigs to determine the effects of adding various levels of wheat screenings to mash-type diets based upon corn and soybean meal when the diets also contained field peas and ground canola seed. Rate of gain was comparable for all treatments containing field peas and ground canola seed (0, 20, 40, or 60% wheat screenings). However, substituting increasing levels of wheat screenings (up to 60% of the diet) increased the feed required per unit of gain ($P<.05$). Meat color was influenced by diet ($P<.01$)

Based on data from the study that evaluated nutrient digestibility, the wheat screenings contained 92% of the digestible energy (DE) of corn while the field peas contained 97% of the DE of corn, and the ground canola seed contained 108% of the DE of corn.

Introduction
The increasing number of crop production alternatives provides livestock producers with a greater number of options for energy and protein sources in diets or rations for their livestock. As these alternative feedstuffs become available, it is necessary to have as much information as possible about these feedstuffs as individual ingredients and in combination with other feeds.

Wheat screenings have been available for many years as an alternative energy feed that is usually higher in crude protein than the grains that they replace. Because screenings are expected to contain less energy than the grains that they replace, performance of growing-finishing swine may be reduced unless supplemental energy is added.

Field peas have the potential for replacing a portion of the soybean meal used in swine diets when a source of supplemental methionine is available.

Canola seed offers opportunities to provide supplemental energy when wheat screenings are included in swine diets and for providing some supplemental methionine when field peas are incorporated into swine diets.

The experiments reported here were conducted to determine the effectiveness of combinations of wheat screenings, field peas, and canola seed as partial replacements for corn and soybean meal in diets for growing-finishing pigs.

Materials and Methods

General Procedures: Two experiments, one at each location, were conducted with growing-finishing pigs. One hundred-five pigs were utilized at the Dickinson location while 160 pigs were used in the equivalent experiment conducted at Fargo. Average initial and final weights were 44 lb and 258 lb at Dickinson and were 40 and 240 lb, respectively, at Fargo.

Diets used in the growing-finishing experiment were:

1) A pelleted corn-soy reference diet;
2) A corn-soy diet base containing 20% field peas and 7.5% canola seed;
3) A corn-soy diet base containing 20% field peas, 20% screenings, and 15% canola seed;
4) A corn-soy diet base containing 20% field peas, 40% screenings, and 15% canola seed; and
5) A corn-soy diet base containing 20% field peas, 60% screenings, and 15% canola seed.

Diet formulations for the growing phase (40 to 120 pounds) are presented in Table 1. The composition of the diets fed during the development phase (120 to 190 pounds) and the finishing phase (190 pounds to market weight) were similar, but contained lower levels of crude protein, amino acids, calcium, and phosphorus.

Diet 1 was ground, mixed, and pelleted by the Northern Crops Institute at Fargo to serve as an internal control diet between, as well as within, each location. The remaining diets were fed in mash (ground) form and were ground and mixed locally. Single-source samples of wheat screenings, field peas, and canola seed were used for both locations.

The screenings used in these experiments contained 32.82% wheat, 8.72% chaff and straw, 7.84% wild oats, 3.13% wild buckwheat, and 47.49% miscellaneous weed seeds (primarily green and yellow foxtail).

Dietary treatments were randomly assigned to pens within weight replicates and individual pigs were assigned at random to pens within outcome groups based on weight, gender, and ancestry.

Carcass data from pigs in the experiment conducted at Dickinson were obtained from pigs slaughtered at a commercial packinghouse. Carcass information from pigs used in the experiment at Fargo was obtained from pigs processed at the NDSU abattoir.

In addition to the growth experiments conducted at each location, a digestibility experiment was conducted at Fargo to determine the digestibility of selected nutrients in the wheat screenings, field peas, and ground canola samples. Each test ingredient was added as a percentage of the body weight of individual pigs to supplement a basal diet formulated to meet the requirements of growing pigs for all nutrients except energy. Nutrient digestibility was calculated on a dry matter basis. The digestibility of nutrients in the test ingredients was determined by the difference between total excretion of undigested nutrients and the excretion of undigested nutrients provided by the basal diet.

Results and Discussion

Animal performance from the experiment conducted at Dickinson: Combined data (Table 2) for pigs grown to market weight in outdoor facilities revealed that pigs fed the pelleted corn-soy and mash-type corn-pea control diets grew faster (P<.01) than pigs fed diets containing screenings. Pigs fed the pelleted control diet, however, were more efficient than any of the pigs receiving peas and screenings (P<.01). Diets in which peas and canola were fed with 0 to 60% wheat screenings had significant variation. Pigs receiving the corn-pea control diet (mash-type) diet grew faster (P<.01) and were more efficient (P<.001) than pigs fed any of the test levels of wheat screenings. Feed efficiency in the presence of screenings declined linearly as screenings level increased (P<.001).

While feed efficiency declined with increasing level of screenings, only minimal differences were recorded with respect to carcass characteristics. Percent lean, fat depth, and fat-free lean index did not differ. Carcasses from pigs fed the control diets (pelleted or mash) had greater loin depth (P<.10) than those receiving screenings, however fat depth was similar.

Animal performance from the experiment conducted at Fargo: For the complete period of the experiment, pigs receiving the pelleted corn-soy diet gained more rapidly and had lower feed:gain values than pigs fed the ground (mash-type) diets. Within the diets containing field peas and canola but with varying levels of wheat screenings, rate of gain values were not statistically significantly different (P>.05). However, the pigs receiving the diet containing 60% screenings were less efficient than pigs fed the diets containing either 20% screenings or no screenings (P<.05).

There were minimal differences in most carcass measurements (hot or cold carcass weight; carcass length; backfat at the first rib, tenth rib, or last rib; muscle pH, or area of the loin muscle). For backfat depth measured at the last lumbar vertebrae, fat depth increased linearly as percentage of screenings in the diet was increased (P<.05). No explanation for this effect is immediately apparent.

There were no differences in subjective color, firmness, or marbling scores due to dietary treatment (P>.05). However, diet influenced color values determined objectively (Minolta) (P<.01).

Implications

Although economic analysis is in progress, the data from these experiments suggest that combinations of ground wheat screenings, field peas and canola seed can be used effectively by growing-finishing swine. Only modest changes in animal performance were noted and only one of the carcass measurements was influenced by level of screenings in the diet. Diet influenced objective meat color.

Knowledge of the digestibility of major nutrients in the wheat screenings, field peas, and canola seed should assist North Dakota Swine Producers in preparing cost-effective diets to be fed to growing-finishing pigs.

Acknowledgments

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Reference:

Thacker, P.A. and R.N. Kirkwood (Eds.). 1990. Nontraditional Feed Sources for Use in Swine Production. Butterworths.

Table 1. Composition of Experimental Diets for the Growing Phase (40-120 pounds).

Description of Special Dietary Composition:

Physcial form: Ingredient (% of diet):	External Reference (Control) Pelleted Diet 1	Control 20% Peas 7.5% Canola Mash (Meal) Diet 2	20% Screenings 20% Peas 15% Canola Mash (Meal) Diet 3	40% Screenings 20% Peas 15% Canola Mash (Meal) Diet 4	60% Screenings 20% Peas 15% Canola Mash (Meal) Diet 5
Corn	69.02	52.55	33.63	20.15	1.66
Wheat screenings	0.00	0.00	20.00	40.00	60.00
Soybean meal, 44%	27.60	16.70	7.93	1.20	0.00
Field peas	0.00	20.00	20.00	20.00	20.00
Ground canola seed	0.00	7.50	15.00	15.00	15.00
L-lysine HC1	0.20	0.12	0.30	0.47	0.45
DL-Methionine	0.10	0.12	0.14	0.17	0.17
L-Threonine	0.03	0.05	0.12	0.20	0.17
L-Tryptophan	0.00	0.01	0.03	0.06	0.05
Dicalcium phosphate	1.45	1.40	1.35	1.20	0.95
Limestone	0.80	0.75	0.70	0.75	0.75
Salt	0.35	0.35	0.35	0.35	0.35
Vitamin & t.m. premix	0.30	0.30	0.30	0.30	0.30
Antibiotic	0.15	0.15	0.15	0.15	0.15
Total	**100.00**	**100.00**	**100.00**	**100.00**	

Table 2. Growing-finishing pig response to increasing levels of wheat screenings in 3-Phase corn-pea diets fed outdoors at the Dickinson Research Extension Center.

Treatments:	Corn/Soy (Pelleted)	Corn/Pea (Mash)	Corn/Pea 20% Scrn (Mash)	Corn/Pea 40% Scrn (Mash)	Corn/Pea 60% Scrn (Mash)	Control vs Pea	Control vs Scrn.	Scrn. vs Linear	SE
Growth:									
Initial Wt., lbs	42.0	42.5	44.0	43.7	47.0				
Final Wt., lbs	259.8	258.8	252.0	256.5	260.8				
Days Fed	106.3	108.6	109.6	115.4	112.4	NS	.009	.046	1.67
Gain/Head, lbs	217.8	216.3	208.0	212.8	213.8	NS	NS	NS	NS
ADG, lbs	2.05	1.99	1.90	1.84	1.90	NS	.004	.085	.039
Feed/Head, lbs	568.8	651.6	673.6	725.1	778.8	.002	.0001	.0001	14.1
Feed/Head/Day, lbs	5.35	6.0	6.15	6.28	6.93	.006	.0001	.0006	.133
Feed:Gain, lbs	2.61	3.01	3.24	3.41	3.64	.003	.0001	.0001	.071
Carcass:									
Slaughter Wt., lbs.	253	250	244	248	253				
Hot Carcass Wt., lbs	180	184	176	179	179	NS	NS	NS	2.87
Percent Yield	71.2	73.4	71.9	72.4	70.9	.043	NS	.055	.477
Percent Lean	53.8	53.9	54.0	53.6	53.9	NS	NS	NS	.60
Fat Depth, in	.69	.73	.68	.70	.69	NS	NS	NS	.033
Loin Depth, in	2.08	2.10	1.99	2.03	1.96	NS	.061	.054	.031
Fat Free Lean Index	49.3	49.0	49.3	49.2	49.4	NS	NS	NS	.394

Table 3. Growing-finishing pig response to increasing levels of wheat screenings in 3-Phase corn-pea diets fed in confinement at Fargo.

Level of screenings:	None	None	20%	40%	60%	
Diet base:	Corn/Soy	Corn/Pea	Corn/Pea	Corn/Pea	Corn/Pea	
Physical form:	Pelleted	Mash	Mash	Mash	Mash	Probability:
Growth:						
ADG, lb.	1.98	1.87	1.84	1.88	1.82	P<0.03
ADFI, lb.	4.89	4.81	4.78	5.01	5.16	N.S.
F/G	2.48	2.58	2.60	2.67	2.84	P<0.01
Carcass:						
Hot carc. wt, lb.	187.4	187.3	191.6	185.9	187.3	N.S.
Cold carc. Wt, lb.	182.3	182.0	186.5	180.7	182.6	N.S.
1st rib fat, in.	1.68	1.74	1.83	1.75	1.75	N.S.
10th rib fat, in.	0.82	0.88	0.92	0.87	0.97	N.S.
Last rib fat	0.95	0.95	1.00	0.96	1.05	N.S.
Muscle pH	5.62	5.61	5.64	5.58	5.61	N.S.
LEA, sq. in.	6.61	6.45	6.75	6.58	6.46	N.S.
Color, subjective	2.00	2.31	2.18	2.06	2.37	N.S.
Firmness	2.37	2.37	2.18	2.25	2.56	N.S.
Marbling	2.00	2.25	2.00	2.06	2.43	N.S.
Color, Minolta L1	58.68	56.62	55.43	56.81	55.06	P<0.01
Color, Hunter 1	51.81	49.56	48.31	49.62	48.00	P<0.01

Table 4. Digestibility of selected nutrients in energy-feeds used in these experiments (Fargo samples).

Item:	Corn	Wheat Screenings	Ground Field Pea	Canola Seed
Dry matter digestibility, %	87.85	76.54	83.56	65.09
Acid-detergent fiber digestibility, %	68.01	50.31	68.93	56.88
Crude protein digestibility, %	66.77	65.28	72.23	74.73
Digestible energy, kcal/kg	3.701	3.410	3.585	3.987

<u>Barley Versus Oat: Which Makes the Superior Forage Crop</u>

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Abstract
Oat *(Avena sativa* L.) is the most popular, cool-season annual forage grown in North Dakota. Research in Minnesota and Wisconsin suggests that barley *(Hordeum vulgare* L.) is superior to oat for forage quality and, in some instances, comparable in yield. A study was begun to determine if barley is equal or superior to oat for forage yield and quality in southwestern North Dakota. Oat and barley cultivars were compared for forage yield in randomized and replicated plots. Selected cultivars also were intercropped with field peas *(Pisum sativum* sub. *arvense* Poir.). Dry matter (DM) yield averaged 2.3 tons/acre for oat but only 1.7 tons/acre for barley. Cultivars developed for forage tended to produce more DM than cultivars developed for grain. No yield advantage resulted when barley or oat was intercropped. These results suggest that oat is superior to barley for dry matter yield in southwestern North Dakota and similar environments.

Introduction
Oat is the most popular, cool-season, annual forage crop grown in North Dakota. Oat comprised approximately 83% of the small grain acreage devoted to hay production in 1997 (E. Stabenow, North Dakota Agric. Stat. Serv., per. comm.). The remaining acreage was comprised of barley (14%) and other (rye, wheat) small grain crops (3%).

Research indicates that barley produces higher quality forage compared with oats in sub-humid regions. Barley had greater nutritive value than oat, triticale *(Triticum x Secale)*, and wheat *(Triticum aestivum* L.) in Minnesota (Cherney and Martin, 1982). Barley forage was highest in digestible dry matter concentration, and lowest in acid detergent fiber concentration. The crude protein (CP) concentration of barley forage was 1.6% greater than oats. Similarly, the CP concentration of barley and barley-pea forage was superior to the CP concentration of oat and oat-pea forage in a study at Dickinson, ND (Carr et al., 1998).

Barley forage yield has been equal or superior to forage yield of oats in sub-humid regions, whether grown alone (Cherney et al., 1982) or with pea as a companion crop for alfalfa *(Medicago sativa* L.) establishment (Chapko et al., 1991). Barley forage yield has been inconsistent compared with oat in North Dakota. ‘Dumont’ and ‘Magnum’ oats were superior to ‘Bowman’ and ‘Horsford’ barley for yield when the cultivars were grown alone and in combination with field pea in 1993 and 1994 (Carr et al., 1998). However, differences in yield between ‘Chopper’, ‘Haybet’, and ‘B 7518’ barley cultivars and Dumont oats were not detected in a subsequent study (Carr et al. 1996). These data indicate that cultivar selection impacts barley performance for forage yield compared with oat. Additional research is needed to determine the yield potential of barley and oat in North Dakota. The objective of this experiment is to determine if barley is superior to other cool-season, annual forage crops and crop combinations for yield and quality.

Materials and Methods

Six barley cultivars developed for forage (Horsford, Haybet, Westford, and three experimentals) and grain (2-rowed = Conlon, Stark, Logan; 6-rowed = Foster, Robust, Stander) were compared with three oat cultivars grown for forage (Celsia, Mammoth, Triple Crown) and two for grain (Paul and Whitestone) for forage yield and quality in 1999. These same cultivars along with Jerry oat will be compared in 2000. Selected barley and oat cultivars also were grown with field pea so that comparisons among barley and oat sole crops and intercrops can be made.

A randomized complete block with four replications was used in 1999. Data will be analyzed using appropriate statistical procedures available from SAS. Results of forage quality data were unavailable when this manuscript was prepared. Forage quality data will be presented in a future manuscript.

Results and Discussion

Moisture content of forage averaged 68% moisture at harvest (Table). Moisture content ranged from 62% for Mammoth oat and Logan and Stark barley, to 77% for Westford and BZ 593-159 barley.

Oat cultivars produced an average DM yield of 2.3 tons/acre compared with 1.7 tons/acre for the barley cultivars (Table 1). The highest yielding oat cultivar, Triple Crown, produced 2.5 tons DM/acre. In comparison, the highest yielding barley cultivar, Westford, produced 2.0 tons. These preliminary results concur with results of earlier research indicating that more forage is produced by oat compared with barley in southwestern North Dakota (Carr et al. 1998). If forage quality analyses determine that barley is a superior forage compared with oat, however, then barley still may produce more kcal/acre, even though the DM yield of oat is greater.

Intercropping barley or oat with pea failed to improve forage yield compared with cereal sole crop (Table 1). These data concur with results of previous research indicating that intercropping failed to provide a forage yield advantage in southwestern North Dakota (Carr et al., 1998). However, the crude protein concentration of forage produced by barley- and oat-pea intercrops generally was superior to the crude protein concentration of forage produced by cereal sole crop.

Conclusions/Implications of Research

First-year results of this multi-year study suggest that oat produces equal or greater amounts of DM/acre compared with barley in southwestern North Dakota and similar environments. However, it is premature to conclude that oat is superior to barley for forage production, in terms of kcal/acre, since results of forage quality analyses are not available. A thorough comparison of the forage value of barley and oat will reported once additional yield and quality data are generated.

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Table 1. Harvest moisture content and dry matter yield of barley, oat, and cereal-pea intercrops in a recropped, dryland environment during 1999 at Dickinson, ND.

Crop	Type	Cultivar[s]	Moisture at harvest	Dry matter
			-%-	-tons/acre-
Oats	Forage			
		Triple crown	74	2.5
		Mammoth	62	2.4
		Celsia	63	2.3
	Grain			
		Whitestone	63	2.4
		Paul	64	2.0
	Oat + pea	Whitestone + Trapper peas	68	2.6
		Paul + Arvika peas	68	2.4
		Paul + Trapper peas	72	2.3
		Whitestone + Arvika	67	2.2
Barley	Forage			
		Westford	77	2.0
		Haybet	63	2.0
		BZ 593-152	76	1.7
		ND 17577	67	1.6
		BZ 593-159	77	1.6
		Horsford	66	1.5
	2-rowed grain			
		Conlon	64	1.7
		Logan	62	1.6
		Stark	62	1.6
	6-rowed grain			
		Robust	66	1.7
		Foster	67	1.6
		Stander	69	1.5
	Barley + pea			
		Haybet + Arvika peas	70	2.2
		Robust + Arvika peas	71	2.1
		Robust + Trapper peas	76	1.9
	Trial Mean		68	2
	C.V. (%)		3.2	13.6
	LSD .05		3	0.4
	Treatment means			
		Oat	65	2.3
		Forage	66	2.4
		Grain	64	2.2
		Barley	68	1.7
		Forage	71	1.7
		Grain	65	1.6

Preliminary Evaluation of Pasture Legumes in an Integrated Crop-Livestock System

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Abstract
Pasture-based cropping systems have improved the economics of wheat production in Australia and Argentina. The objective of this research is to identify forage legume species that are adapted to similar systems in North Dakota. A study was begun in which ten legume species were seeded in randomized and replicated plots in 1999 at Dickinson, ND. Plots were divided into weeded and weedy sections. Preliminary results suggest that barrel medic *(Medicago truncatula* Gaertn. cv. Parabinga)), black medic *(Medicago lupulina* L. cv. George), and snail medic *(Medicago scutellata* [L.] Mill. cv. Sava), along with alfalfa *(Medicago sativa* L. cv. Ladak) and sweetclover *(Melilotus officinalis* [L.] Lam.), might be suitable pasture crops in pasture-based cropping systems. Berseem clover *(Trifolium alexandrinum* L. cv. Bigbee) also may have potential, although an inability to reseed may limit the suitability of this legume species for pasture in pasture-based cropping systems.

Introduction
Negative economic returns were projected for many annual crops grown for grain or seed in North Dakota in 1999. For example, returns to labor and management were estimated to be -$13.32/acre for spring wheat *(Triticum aestivum* L.), -$30.20/acre for feed barley *(Hordeum vulgare* L.), and -$24.02/acre for oats *(Avena sativa* L.) (Swenson and Haugen, 1998). Among broadleaf crops, returns to labor and management were projected to be -$17.39/acre for oil-type sunflower *(Helianthus annuus* L.), -$6.65/acre for canola *(Brassica campestris* L. and *B. napus* L.), and -$17.82/acre for peas *(Pisum sativum* L.).

Economic reality suggests that new production and marketing methods are needed for annual grain and seed crops to be grown profitably in the Great Plains. Forage-based cropping systems developed in Argentina and Australia enhanced the economic and environmental sustainability of grain and seed production in these two countries earlier in this century. These cropping systems use a grazed pasture period to replenish the soil with nutrients, improve soil tilth, and control weeds. Annual or perennial legume species during the pasture phase are rotated with wheat and other grain or seed crops over a two- to nine-year period.

Our overall goal is to develop pasture-based cropping systems based on Argentine and Australian models that are environmentally and economically superior to conventional, grain-based cropping systems in the Great Plains. The objective is this study is to identify forage legume species that are adapted to growing conditions in southwest North Dakota and have potential in pasture-based, grain- and seed-cropping systems.

Materials and Methods

Alfalfa, Austrian winter pea (*Pisum sativum* subs. *sativum* var. *arvense* [L.] Poir.), barrel medic, berseem clover, birdfoot trefoil *(Lotus corniculatus* L. cv. Norcen), black medic, sanfoin *(Onobrychis viciifolia* Scop. cv. Eski), snail medic, subterranean clover *(Trifolium subterraneum* L.), and sweetclover were seeded and compared for forage yield in both hand-weeded and weedy areas within plots in 1999. Above-ground weed growth was collected to provide an indication of the relative competitiveness of the pasture crops during the seeding year. Data were analyzed using appropriate statistical procedures. Legume plant counts and forage yield will be determined in 2000 and possibly 2001 so that legume species with the greatest potential for success at re-establishing or maintaining productive pasture can be identified.

Results and Discussion

Legume forage yield averaged 1.9 tons dry matter (DM)/acre in weeded environments across plots (Table 1). Austrian winter pea and sweetclover produced more forage than other legume species, except for barrel medic. Equal amounts of forage were produced by alfalfa, black medic *(Medicago lupulina* L. cv. George), berseem clover *(Trifolium alexandrinum* L. cv. Bigbee), and snail medic (Medicago scutellata [L.] Mill. cv. Sava). Subterranean clover was decumbent, produced very little forage, and failed to produce seed.

Forage yield averaged 1.3 tons DM/acre for the legume species in weedy environments across plots (Table 1). Austrian winter pea produced more forage than other legume species, followed by barrel medic and sweetclover. Alfalfa, berseem clover, black medic, and snail medic produced less forage than either barrel medic or sweetclover, but more than sanfoin and birdsfoot trefoil.

Weed production was highest in sanfoin and birdsfoot trefoil plots, followed by berseem clover plots. Weed biomass was equal in alfalfa, barrel medic, black medic, snail medic, and sweetclover plots. Weed production was lowest in Austrian winter pea plots.

Conclusions/Implications of Research

Austrian winter peas were equal or superior to other species for forage yield in both weeded and weedy environments in 1999, when pastures first were established. Peas are an annual, non-reseeding legume that only have limited potential as multi-year pasture crop. Berseem medic produced less forage than Austrian winter peas and also is an annual, non-reseeding legume. Biennial sweetclover produced 1.7 tons DM/acre in weedy environments, was relatively competitive with weeds, and may have potential as a multi-year pasture crop if sweetclover is self-seeding after first being established. Barrel medic, black medic, and snail medic, along with alfalfa, seem to have the greatest potential as pasture, as long as stands can persist or can be reestablished by self-seeding methods. Birdsfoot trefoil, sanfoin, and subterranean clover have the least potential as pasture legumes, based on preliminary results of this study. Additional data will be generated by this multi-year study.

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Table 1. Forage yield of selected legume species in hand-weeded and weedy environments in 1999 at Dickinson, ND.

		-- Hand-weeded --	----------------- Weedy ----------------------	
Legume species	**Cultivar**	**Forage dry matter**	**Forage dry matter**	**Weed dry matter**
		----------------------------------Mg/ha	--------------------------------	
Alfalfa	Ladak	1.6	1.2	1.1
Austrian winter pea	Common	3.2	3.4	0.1
Barrel medic	Parabinga	2.6	2.0	0.9
Berseem clover	BigBee	2.0	1.2	1.6
Birdsfoot trefoil	Norcen	1.0	0.3	2.5
Black medic	George	1.7	1.2	1.1
Sanfoin	Eski	0.8	0.2	2.3
Snail medic	Sava	1.2	0.7	0.7
Subterranean clover	--	--	--	--
Sweetclover	Common	2.8	1.7	1.2
Mean		1.9	1.3	1.3
CV (%)		24.8	23.9	25.7
LSD .05		0.8	0.5	0.6

Defoliation applied at some phenological growth stages negatively affects grass plants

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Abstract

Timing grazing according to phenological growth stages of grass plants is important. Grazing applied at some phenological growth stages can have detrimental effects on grass growth and herbage production. These stages occur during early spring growth before plants have reached the third-leaf stage and during the period after secondary tillers have been stimulated to grow and before they reach the third-leaf stage. Selective heavy fall and winter grazing of late-stimulated secondary tillers and of fall-initiated lead tillers of cool-season grasses also negatively affects plant growth and herbage production. Grazing applied at some phenological growth stages can produce positive effects on grass growth and herbage production by beneficially manipulating the biological processes grass plants have developed as defoliation resistance mechanisms: light defoliation of grass plants between the third-leaf and flowering phenophases stimulates growth of secondary tillers from axillary buds and stimulates activity levels of symbiotic organisms in the rhizosphere (Manske 1998).

Grass Leaf Development

Young grass leaves develop from leaf bud primordia produced in the apical meristem. Almost all cells of the leaf are formed while the leaf is a minute bud (Langer 1972). Growth of the leaf results from expansion in cell size (Esau 1960, Dahl 1995) and increase in weight (Coyne et al. 1995). The new growing leaf draws carbohydrates from roots, stems, or older leaves until its maintenance and growth requirements can be met by assimilates produced by the new leaves (Langer 1972, Coyne et al. 1995). Defoliation of leaf material before the tiller has reached the third-leaf stage has the potential to disrupt the formation of leaf bud primordia for the tiller. When the tiller is between the 3.0 and 3.5 leaf stage, the apical meristem ceases to produce leaf bud primordia and begins to produce flower bud primordia (Frank 1996, Frank et al. 1997). The previously formed leaf bud primordia continue to grow and develop (Esau 1960, Langer 1972), with the oldest cells at the tip (Langer 1972, Dahl 1995) and the oldest leaf outermost (Rechenthin 1956, Beard 1973). In the Northern Great Plains, most native cool-season grasses reach the third-leaf stage around early June, and most native warm-season grasses reach the third-leaf stage around mid June. Many domesticated cool-season grasses reach the third-leaf stage around late April and early to mid May.

Grazing before Third-Leaf Stage

Cool-season grasses initiate lead tiller growth during the fall and resume active growth the next spring. Spring growth of cool-season grass leaves depends both on carbohydrate reserves and on photosynthetic products from the portions of fall-initiated tiller leaves that have overwintered and regreened. Spring growth of warm-season grass leaves depends initially on carbohydrate reserves and later both on carbohydrate reserves and on photosynthetic product from young leaves. Grass plant growth and development depend on adequate carbohydrate reserves in early spring because the amount of photosynthetic product synthesized by early growing leaves is insufficient to meet the requirements for leaf growth (Heady 1975, Coyne et al. 1995). Grass growth also requires that the plant have adequate leaf area to provide photosynthetic product for early growing leaves. The total nonstructural carbohydrates of a grass plant are at low levels following the reduction of reserves during the winter respiration period, and the carbohydrate reserves remaining in the roots and stems are needed for both root growth and initial leaf growth during early spring. The low quantity of reserve carbohydrates may not be adequate to supply the entire amount required to support root growth and also support leaf growth until sufficient leaf area is produced to provide the photosynthetic assimilates required for plant growth and other processes (Coyne et al. 1995). Removal of aboveground material from grass plants not yet at the third-leaf stage deprives plants of foliage needed for photosynthesis and increases the demand upon already low levels of carbohydrate reserves when sequential leaves grow. The quantity of herbage produced by a grass plant after it has been grazed is dependent on the levels of carbohydrates present in the remaining herbage at the time of defoliation (Coyne et al. 1995). Defoliation of the tiller before the third-leaf stage, when the plant is low in carbohydrates, results in reduced growth rates of herbage production (Coyne et al. 1995) and negatively affects the peak herbage biomass production later in the year (Manske 1994).

Grazing after Third-Leaf Stage

Defoliation of leaf material after the third-leaf stage affects herbage biomass production in relation to the amount of leaf material removed. The amount of leaf area capable of conducting photosynthesis that remains after defoliation is an important factor affecting the quantity of herbage produced by the grazed grass plants. Severely defoliated plants depend upon stored carbohydrates for new plant growth (Briske and Richards 1995). There is an additional cost to the plant when the photosynthetic system needs to be replaced from stored carbohydrates. This implied reduction in efficiency results in low growth rates and reduced quantities of herbage biomass produced (Coyne et al. 1995). Additional restrictions inhibit herbage production when the stored carbohydrates are at low levels (Coyne et al. 1995). Plants with sufficient leaf area remaining after defoliation utilize some stored carbohydrates for development of new leaf tissue (Briske and Richards 1995, Coyne et al. 1995), but the source of carbohydrates for most new growth is current photosynthates, which are preferentially allocated to areas of active shoot growth (Richards and Caldwell 1985, Briske and Richards 1995). Replacement of leaf tissue from current assimilates has a lower cost to the plant than growth from stored carbohydrates and results in higher growth rates and increased production of herbage biomass (Coyne et al. 1995).

Defoliation after the third-leaf stage stimulates vegetative reproduction from axillary buds by reducing apical dominance (Manske 1998). Light defoliation of grass plants between the third-leaf and flowering stages stimulates growth of secondary tillers and stimulates rhizosphere organism activity (Manske 1998). The presence of higher levels of carbohydrate reserves before defoliation increases the number of stimulated tillers that grow (Coyne et al. 1995), and the resulting development of secondary tillers increases herbage biomass. Rate of growth of secondary tillers is variable depending on the growing season periods during which axillary bud growth is stimulated. Early stimulated secondary tillers require less time to reach the third-leaf stage than do late-stimulated tillers. Grazing periods should be synchronized with the growth rate of the stimulated secondary tillers so that defoliation is applied only after they reach the third-leaf stage.

Grazing during Late Season

In the fall, cool-season grass species initiate lead tillers, which overwinter. The following spring, the tiller leaf cells with intact cell walls regreen, resume active growth, and provide photosynthetic product for new leaf growth (Briske and Richards 1995, Manske 1998). Late-stimulated secondary tillers that start development during late June or early July usually do not produce flower heads and also frequently overwinter, resuming active growth the subsequent growing season (Briske and Richards 1995, Manske 1998). Selective severe fall and winter defoliation of late-stimulated secondary tillers and cool-season fall-initiated lead tillers reduces their contribution to the ecosystem and results in greatly reduced grass density and herbage production the following year (Manske 1998) because with late-season defoliation plants are unable to replenish adequate amounts of reserve carbohydrates to support active growth (Coyne et al. 1995).

Time of Grazing Affects Herbage Biomass

Grazing early in the spring greatly affects the percentage of the potential peak aboveground herbage biomass produced. Studies conducted in the Northern Great Plains have evaluated starting dates for seasonlong grazing management (Campbell 1952, Rogler et al. 1962, Manske 1994). The data from three locations show that if seasonlong grazing is started in mid May on native range, 45-60% of the potential peak herbage biomass will be lost and will never be available to grazing livestock. If the starting date of seasonlong grazing is delayed until early or mid July, nearly all the potential peak herbage biomass will grow and be available to the grazing livestock, but the nutritional quality will be at or below the crude protein levels required for a lactating cow. If the starting date is deferred until after mid July, less than peak herbage biomass will be available to grazing livestock and nutritional quality will be low because of senescence and the translocation of cell material to belowground structures. Data from the studies indicate that a starting date between early June and early July results in the fewest negative effects on herbage biomass production and nutritional quality of the available forage. The dates at which native range grasses reach the third-leaf stage indicate that seasonlong grazing management should delay grazing until mid June, but rotation systems could begin grazing on native range in early June. Domesticated cool-season grasses such as crested wheatgrass and smooth bromegrass reach their third-leaf stage in late April or early May and can serve as complementary pastures before native range pastures are ready for grazing in the spring. Numerous domesticated wildrye varieties translocate their aboveground cell material to belowground structures later in the fall than do other grasses. These varieties of wildrye can serve as complementary pastures for grazing in the fall.

Time of Grazing Affects Animal Performance

The physical damage grass plants sustain from early spring grazing applied before the third-leaf stage and from selective heavy fall and winter grazing of late-stimulated secondary tillers and fall-initiated lead tillers reduces herbage production and negatively affects animal performance and production (Manske 1996, Manske and Sedivec 1999). Stocking rate, animal gains, net return per cow/calf pair, and net return per acre are reduced and pasture costs and costs per pound of calf gain are increased on management strategies that heavily graze native range fall and winter and/or graze during early spring before the third-leaf stage.

Grazing Readiness

The 3.0 to 3.5 leaf phenological growth stage is the best indicator of the grass plants' grazing readiness. Grazing grass plants prior to the third-leaf stage negatively affects grass growth, herbage production, and animal production and exerts a negligible stimulatory effect on tillering (Olson and Richards 1988, Vogel and Bjugstad 1968). Starting grazing after the third-leaf stage allows plants to establish sufficient leaf area to produce adequate amounts of photosynthetic assimilate to meet leaf-growth requirements and allows leaf bud primordia in the apical meristem to develop completely. Defoliation after the third-leaf stage stimulates secondary tiller development and rhizosphere organism activity. Secondary tillers should be allowed to reach the third-leaf stage before grazing. Late-stimulated secondary tillers and fall-initiated lead tillers should be managed in the fall and winter so that they retain adequate leaf material to produce sufficient carbohydrate reserves for winter respiration and to regreen and contribute sufficient photosynthate for active root and leaf growth in the spring.

Management Implications

The grazing management strategy that times grazing periods according to phenological growth stages of grasses is the twice-over rotation system with 3 to 6 native range pastures and spring and fall domesticated cool-season complementary pastures. The grazing periods of this management system are synchronized with the phenological growth stages of grasses so that the negative effects of grazing are minimized and the beneficial effects of grazing are enhanced.

Summary

Effective grazing management strategies are based on the phenological growth stage of grasses. Grazing early spring growth before grass plants reach the third-leaf stage and grazing stimulated secondary tillers during periods before they reach the third-leaf stage negatively affect grass growth and result in reduced herbage production. Native cool-season grasses reach the third-leaf stage around early June, and native warm-season grasses reach the third-leaf stage around mid June. Many domesticated cool-season grasses reach the third-leaf stage four to five weeks ahead of native range grasses. Secondary tillers reach the third-leaf stage at variable times, depending on the growing season period during which tiller development is initiated. Early stimulated secondary tillers require less time to reach the third-leaf stage than do late-stimulated tillers. Late-stimulated secondary tillers and cool-season fall-initiated lead tillers can overwinter and resume active growth the next growing season. Selective severe fall and winter grazing of late-stimulated secondary tillers and of fall-initiated lead tillers of cool-season grasses negatively affects grass growth and herbage production.

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Stair-stepped growth patterns in heifer development programs

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Research Summary
The stair-stepped growth regimen increased overall trial gains, improved growth efficiencies and reduced total dry matter consumed in both heifer calves and bred heifers. Subsequent calving performance and milk production data on heifers in this study will be monitored for assessment of carryover effects of heifer developmental regimen.

Introduction
Research has demonstrated in a number of species increases in subsequent milk production when females are exposed to a stair-stepped growth regimen during development. Stair-stepped growth is accomplished by nutritionally alternating phases of low and rapid growth rates. These studies are part of a series of ongoing experiments designed to determine the effect of a stair-stepped growth regimen on growth performance and subsequent lactational potential of beef heifers. The first study imposed the growth regimen in heifer calves from weaning to breeding. The second study focused on bred heifers prior to first calving. Only growth and calving performance are presented in this report.

Materials and Methods
Experiment 1. Forty-eight heifer calves were blocked into three weight groups and randomly assigned to 6 feedlot pens with group (8 heifers/pen; 2 pens/group). Pens within group were then assigned one of two dietary regimens (1 pen/treatment/group). Dietary regimens represented heifers nutritionally managed for a continuous rate of gain (1.5 lb/d) for 20 wk (CO1) or for a minimal rate of gain for 10 wk followed by a rapid rate of gain for 10 wk (SS1). The minimal rate of gain was imposed by dietary energy restriction. Metabolizable energy concentration (ME) of the restricted phase diet was similar to diet used in first 10-wk phase of CO1, however dry matter intake (DMI) was restricted to 70% of DMI of CO1 heifers. Protein concentrations (CP) was increased in the restricted diet to allow for similar daily intakes between the dietary regimens in the first phase. Following the restricted gain phase, SS1 heifers were given ad libitum access to a high energy diet (130% ME and 100% CP of CO2 diet) for 10 wk. Differences in diets between phases for CO1 were primarily in ME to account for expected environmental changes. Following the 20-wk study, all heifers were managed similarly through breeding. Diets used in the restricted and rapid growth phases are shown in Table 1.

Diets were mixed and fed daily. Intake of CO1 heifers during the restricted phase of growth was paired to CO1 heifers daily within weight group. "Minimal feed refusal" bunk management was employed in CO1 heifers to accommodate calculation of intake restriction. Body weight (BW) and body condition score (BCS) was recorded every 14 d. Estrus was synchronized and heifers were artificially inseminated 12 hr following standing heat. Heifers were then exposed to intact bulls for the remainder of the breeding season.

Data were analyzed as a randomized complete block design using standard analysis of variance procedures and pen as the experimental unit.

Experiment 2. Twenty bred heifers were randomly assigned to four feedlot pens. Pens were then assigned to one of two dietary regimens (2 pens/regimen). The structure of the experiment was similar to Experiment 1, with the following exceptions. The experimental period consisted of two 9-wk phases (18 wk total). Control (constant gain; CO2) heifers were nutritionally managed for 1.0 lb/d. Diets used in the restricted and rapid growth phases are shown in Table 2. Experimental regimens (CO2 and stair-stepped [SS2]) ended when the first heifer calved and all heifers were subsequently managed similarly through weaning.

Data were analyzed as a completely random design using standard analysis of variance procedures and pen representing the experimental unit.

Results and Discussion

Experiment 1. In heifer calves, initial BW (P=.35) and BCS (P=.42) did not differ between dietary regimen (Table 3). During the restricted phase (first 10 wk), BW (P<.01), BCS (P=.06), average daily gain (ADG; P<.01) DMI (P<.01) and growth efficiency (GE; P<.01) were all depressed by SS1. Intakes were reduced 75% during the restricted phase. During the rapid growth phase (final 10 wk), BW (P=.01), ADG (P<.01), DMI (P=.05) and GE (P<.01) were all improved by SS1. Final BCS (P=.17) did not differ between growth regimens. Over the entire period (20 wk), ADG (P=.02) and GE (P<.01) were improved by SS1, while DMI (P<.01) was reduced.

Experiment 2. In bred heifers, initial BW (P=.09) was greater for CO2 heifers. Initial BCS (P=.35) did not differ between dietary regimens (Table 4). During the restricted phase (first 9 wk), BW (P=.08), ADG (P=.10) and DMI (P<.01) were depressed by SS2. At the end of the restricted phase, BCS (P=.15) and GE (P=.18) were not statistically effected by dietary regimen. Intakes were reduced 76% during the restricted phase. Gain data was terminated at wk 17 (heifers began calving 4 days prior to end of wk 18), intake data continued through wk 18. During the rapid growth phase, BW (P<.01), BCS (P=.06), ADG (P<.01), DMI (P=.05) and GE (P<.01) were improved by SS2. Over the entire 18 wk period, ADG (P<.01) and GE (P<.01) were improved, while DMI (P<.01) was depressed, by SS2. Calving date (P=.07) was reduced 4.8 d by SS2. Calf birth weight (P=.33) were not influenced by growth regimen.

The desired level of intake restriction was not achieved in either experiment. Restriction averaged 75.5% across both experiments as opposed to the desired level of 70%. Future studies will need to address the restriction protocol with respect to feed deliveries.

Dry matter intakes in Experiment 2 were lower than expected for both experimental treatments. Although SS2 heifers were able to experience a compensatory growth response despite this intake reduction, CO2 heifers reflected the lower intake with corresponding lower growth. Nonetheless, in both experiments, the experimental stair-stepped growth response was achieved. Overall performance in both experiments was consistent with previous studies conducted at the Center. The stair-stepped growth regimen increased overall trial gains, improved growth efficiencies and reduced total dry matter consumed. Subsequent calving performance and milk production data on heifers in this study will be monitored for assessment of carryover effects of heifer developmental regimen.

Table 1. Diet composition (as fed basis) in Experiment 1 (heifer calves).

	CO1	SS1
Restricted phase		
Hay	13.41	46.03
Corn silage	79.18	35.62
Grain-based meal[a]	7.41	18.35
Compensation phase[b]		
Hay	11.60	10.21
Corn silage	80.41	28.55
Grain-based meal[a]	7.72	60.80
Total		
Hay	11.67	24.94
Corn silage	79.80	31.46
Grain-based meals	7.57	43.35

[a]Grain-based meals were formulated and mixed to specifications by Land O' Lakes/Harvest States, Inc. (Dr. Jeff Heldt, Billings, MT).
[b]216 lb of an MGA containing supplement was fed to both groups during the compensating phase as part of a estrous synchronization protocol.

Table 2. Diet composition (as fed basis) in Experiment 2 (bred heifers).

	CO2	SS2
Restricted phase		
Hay	72.45	73.73
Grain-based meal[a]	27.55	26.27
Compensation phase		
Hay	71.67	18.40
Grain-based meal[a]	28.33	81.60
Total		
Hay	72.11	44.27
Grain-based meals	27.89	55.73

[a]Grain-based meals were formulated and mixed to specifications by Land O' Lakes/Harvest States, Inc. (Dr. Jeff Heldt, Billings, MT).

Table 3. Animal performance in Experiment 1 (heifer calves).

	CO1	SS1	P-value
Initial conditions			
Body weight, lb	662.8	664.9	.35
Body condition score	6.2	6.1	.42
Restricted phase (10 wk)			
Body weight, lb	811.8	719.6	<.01
Body condition score	6.7	5.5	.06
Average daily gain, lb/d	2.13	.78	<.01
Dry matter intake, lb/d	19.7	14.7	<.01
Growth efficiency (gain/intake)	.108	.053	<.01
Compensating phase (10 wk)			
Body weight, lb	942.8	966.7	.01
Body condition score	7.3	7.6	.17
Average daily gain, lb/d	1.87	3.53	<.01
Dry matter intake, lb/d	20.5	20.9	.05
Growth efficiency (gain/intake)	.091	.169	<.01
Overall performance (20 wk)			
Average daily gain, lb/d	2.00	2.16	.02
Dry matter intake, lb/d	20.1	17.8	<.01
Growth efficiency (gain/intake)	.100	.121	<.01

Table 4. Animal performance in Experiment 2 (bred heifers).

	CO2	SS2	P-value
Initial conditions			
Body weight, lb	1032.0	1012.4	.09
Body condition score	6.9	6.4	.35
Restricted phase (9 wk)			
Body weight, lb	1102.4	1036.5	.08
Body condition score	6.5	6.0	.15
Average daily gain, lb/d	1.12	.38	.10
Dry matter intake, lb/d	23.7	18.0	<.01
Growth efficiency (gain/intake)	.047	.021	.18
Compensating phase (8 wk)			
Body weight, lb	1085.6	1203.9	<.01
Body condition score	6.2	7.0	.06
Average daily gain, lb/d	-.03	2.99	<.01
Dry matter intake, lb/d	17.7	19.4	.05
Growth efficiency (gain/intake)	-.017	.154	<.01
Overall performance (18 wk)			
Average daily gain[a], lb/d	.45	1.61	<.01
Dry matter intake, lb/d	20.6	18.6	<.01
Growth efficiency[a] (gain/intake)	.022	.086	<.01
Calving date	Mar 1	Feb 25	.07
Birth weight, lb.	85.2	83.5	.33

[a] Average daily gain calculated over 17 wk and intakes over 18 wk.

Comparison of the effect of Ralgro®, Revalor-G® and Compudose® on yearling beef steers in the Northern Great Plains[abc]

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Abstract
Growth-promoting implants were compared in yearling steers grazing native range in the Northern Great Plains. Use of implants improved final weight and seasonal gain over non-implanted control steers. Two estrogenic-based implants (Ralgro and Compudose) were not different in their ability to enhance growth performance. A combination androgenic/estrogenic-based implant (Revalor-G) enhanced growth performance over that of the estrogenic-based products. When weight gain is important objective of cattle producers grazing yearling steers, use of growth-promoting implants should be considered.

Introduction

Many producers in southwestern North Dakota graze yearling steers throughout the summer. Economics of this type of enterprise is largely a function of purchase and sale prices and weight gain during the grazing season. Growth implants are often used to enhance average daily gains of grazing steers. Once producers decide to consider implant use in a yearling operation, they have several options regarding product selection during the grazing season. The objective of the this trial was to determine the effect of implant selection (Ralgro®, Revalor-G® and Compudose®) on growth rate of yearling steers grazing predominantly native range pastures in the Northern Great Plains.

Materials and Methods

The trial was conducted at the ranch of Mr. Allen Gasho (801 Highway 16, Beach, ND 58621) in western North Dakota. Three-hundred-twenty-three (323) predominantly Angus and Angus-X yearling steers grazed in a seasonlong strategy on predominantly native range pastures in 1999. Grazing began on May 12 and continued through August 9 (89 d of grazing). Steers were individually weighed (unshrunk), identified (2 ear tags; one large easily read and one smaller with higher degree of retention) and assigned to an implant treatment at the initiation of grazing. Treatments included no implant (47 steers) or

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[a] Authors wish to thank Allen and Betty Gasho for their supply and management of cattle and to Schering-Plough Animal Health for grant support.

[b] Mention of trade names is solely to identify materials used and does not constitute endorsement by North Dakota State University.

[c] Ralgro®, 36 mg zeranol, Schering-Plough Animal Health; Compudose®, 25.7 mg estradiol, Vetlife, Inc.; Revalor-G®, 8 mg estradiol and 40 mg trenbolone acetate, Hoechst.

implanted with either Ralgro® (92 steers), Revalor-G® (92 steers) or Compudose® (92 steers). For the purposes of implant assignment, steers were segregated into groups of seven as they sequentially moved through the chute to be processed. Implant treatments were assigned to steers in the 7-head group roughly in the following order: Ralgro®, Revalor-G®, Compudose®, no implant, Compudose®, Revalor-G®, Ralgro®. Initial individual weights were recorded as steers left the headgate following ear tagging and implanting. Administration of the implants was in accordance to manufacturer recommendations as to technique and ear placement. Following recording of initial weights, steers were sorted into three pasture groups roughly by weight and/or ownership without respect to implant treatment. Steers were weighed (unshrunk) at the end of the grazing season and total weight and average daily gain calculated. Three steers were not present at the final weighing (2 Compudose® and one Revalor-G®) and were not included in final data analysis. These steers were subsequently located in an adjacent pasture.

Weight gain data was analyzed as a completely randomized block design using analysis of variance with pasture group representing the blocking factor. Since there were no interactions between implant treatment and pasture group ($P>.78$), animal within implant treatment represented the experimental unit for data analysis. Significant ($P<.1$) implant effects were described using contrasts comparing no implant to implants, androgenic/estrogenic-based to estrogenic-based implants (Revalor-G® vs Ralgro® and Compudose®) and among estrogenic-based implants (Ralgro® to Compudose®).

Results

Initial conditions of the trial are presented in Table 1. In the process of administering implants to treatment steers (92/group), 96, 98 and 92 Ralgro®, Revalor-G®, and Compudose® implants were used. Overall, steers weights averaged 686.8 lb and ranged from 493 to 939 lb. There were no difference ($P=.46$) in initial weight among treatment groups.

Pasture group (Table 2) significantly affected initial ($P=.001$) and final ($P=.001$) weights and weight gains ($P=.02$). Pasture group 1 had the heaviest initial and final weights and the lowest weight gains. Initial and final weights were lowest for pasture group 3 and intermediate for pasture group 2. Weight gains did not follow this pattern. Total weight and average daily gain were greatest for pasture group 1, while gains for pasture group 3 were intermediate.

Three steers were not present at final weighing. Initial weight of steers present at final weighing was not different ($P=.66$) among implant treatment groups. Final weight ($P=.06$) and total and average daily gain ($P=.001$). followed similar pattern with regard to treatment differences. Implanting steers produced heavier final weights ($P=.05$) and larger gains ($P=.001$) over the grazing season. Revalor-G® implanted steers had heavier final weight ($P=.06$) and larger gains ($P=.02$) compared to Ralgro® and Compudose® implanted steers. There were no differences between Ralgro® and Compudose® implanted steers with respect to final weight ($P=.59$) or gain ($P=.97$).

Implications

Although there were differences among pastures in overall performance, implant response on liveweight gain of yearling steers was similar within pastures. In this trial, the utilization of growth-promoting implants resulted in improved performance over nonimplanted contemporaries. Among implanted steers, the androgenic/estrogenic-based implant enhanced performance over either of the estrogenic-based implant products. There were no differences in grazing performance between the estrogenic-based implants.

Table 1. Summary table of initial weights for S-P implant study.

	Implant treatment				
	No implant	**Ralgro**	**Revalor-G**	**Compudose**	**Overall**
Number of steers	47	92	92	92	323
Num. of implants used	-	96	98	92	-
Initial weight (lb)	694.7	688.6	689.0	678.9	686.8
SD[a] (lb)	55.18	59.64	57.43	66.54	60.48
Minimum weight (lb)	542	548	562	493	493
Maximum weight (lb)	812	930	840	939	939

[a] Standard deviation.

Table 2. Summary table of final weights and gains for pasture groups in S-P implant study.

	Pasture group			
	1	**2**	**3**	**P-value[a]**
Number of steers	37	244	39	-
Initial weight (lb)	737.4	689.2	634.3	.001
SE[b] (lb)	9.06	3.66	8.85	
Final weight (lb)	972.5	943.0	882.4	.001
SE (lb)	10.15	4.1	9.91	
Total weight gain (lb)	235.2	253.8	248.1	.02
SE (lb)	6.15	2.48	6.00	
Average daily gain (lb)	2.64	2.85	2.79	.02
SE (lb)	.069	.028	.067	

[a] Probability of at least one of the pasture group means within a row is different from the others.
[b] Standard error of treatment means.
[x,y,z] Means within a row with different subscripts differ. Individual pairwise mean comparisons differ (P<.005).

Table 3. Summary table of final weights and gains for treatments in S-P implant study.

	Implant treatment					P-value[a]			
	No implant	Ralgro	Revalor-G	Compudose		1	2	3	4
Number of steers	47	92	91	90		-	-	-	-
Initial weight (lb)	693.4	686.4	686.8	681.2		.66	.32	.66	.53
SE[b] (lb)	8.46	6.72	6.54	6.53					
Final weight (lb)	918.6	934.9	947.1	930.0		.06	.05	.06	.59
SE (lb)	9.47	7.52	7.32	7.32					
Total weight gain (lb)	225.1	248.6	260.3	248.8		.001	.001	.02	.97
SE (lb)	5.73	4.55	4.43	4.43					
Average daily gain (lb)	2.53	2.79	2.92	2.80		.001	.001	.02	.97
SE (lb)	.064	.051	.050	.050					

[a] Probability values for specific mean comparisons. 1 = at least one of the treatment means within a row is different from the others. 2 = No implanted steers differed from implanted steers. 3 = Revalor-G implanted steers differed from Ralgro and Compudose implanted steers. 4 = Ralgro implanted steers from Compudose implanted steers.
[b] Standard error of treatment means.

Mineral concentrations and availability of forages for grazing livestock in the Northern Great Plains[d]

INTERIM PROGRESS REPORT

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Introduction

Matching animal requirements for minerals to available supply from a base diet forms the basis for designing appropriate supplementation programs. Availability of minerals must be stressed because it encompasses dietary concentration, digestibility and potential antagonistic relationships with other dietary nutrients. Understanding the various factors that affect availability is essential if livestock producers are to minimize production bottlenecks due to mineral deficiencies in a cost-effective manner. This project is designed to help increase the understanding of mineral availability of forages in the Northern Great Plains and to provide information to producers regarding base mineral supply to grazing cattle. This information could then be used to help formulate relevant, cost effective mineral supplementation programs for North Dakota producers.

Project objectives.

A. To compare the influence of grazing system with respect to seasonal changes on the nutritive value of native range in western North Dakota.

B. To evaluate the effect of increasing intake of a forage and forage type on mineral metabolism.

C. To evaluate the effect of maturity, water, nitrogen and growing degree days on the chemical composition of leaf and stem tissue of a cool-season grass.

Materials and Methods

Three experiments have been previously conducted that address varies aspects of mineral nutrition of grazing cattle. Collectively these studies address seasonal/maturity changes in nutritive quality of native range/pasture plants in western North Dakota, the effect of forage intake on mineral bioavailability, and the effects of water stress, soil fertility and grazing management on mineral concentrations of grasses. The limiting factor in each of these experiments is the high cost of nutrient, particularly mineral, analyses.

Objective A. The first experiment is being conducted at the Manning ranch of the Dickinson Research Extension Center (L. Manske). In 1983, two grazing systems were established in replicated pastures. Grazing management included a 4.5 month seasonlong system and a 4.5 month rotational grazing system (3 pastures grazed twice in succession each year). Grazing management in each system has remained

[d] Partial funding for this project was provided by a grant from the North Dakota State Board of Agricultural Research (SBAR).

constant since they were originally initiated. Although forage samples have been collected each year, samples from only 3 years have been selected for complete nutrient analysis. Selected years received relatively normal precipitation (76 to 124% of long term average precipitation). In addition, years were selected to assess long term changes due to grazing system (1983, 1989 and 1995).

Objective B. In the second experiment (E. Grings), two animal trials focused on determining the effect of dry matter intake on mineral bioavailability from forages. In the first trial, 24 steers were allotted to one of 4 treatments consisting of one of two forages fed at two levels of intake for 91 days. Subsamples of plasma, internal organs, skeletal muscle, and rib were collected for analysis of mineral concentrations. A second trial was conducted to determine the apparent absorption and retention of minerals in steers fed at two levels of intake. After 90 days of receiving their respective diets, fecal and urine subsamples were retained for mineral analysis. After removal from the crates, steers were slaughtered, body tissues weighed and subsamples collected for mineral analysis as in the first experiment.

Objective C. In the third experiment (J. Karn), Russian wildrye plots were established in a rain out shelter. Diploid and tetraploid genotypes and 10 and 134 kg/ha N levels were randomly established within four replicates of two water levels (50 and 100% of normal precipitation). Samples were collected at four stages of maturity beginning in May and ending in June. After collection, samples were separated into leaf, stem and head portions according to the presence of each. Mineral analyses will be conducted on plant tissue of each class as in first experiment (objective A).

Results and Discussion (Interim Progress Report)
Objective A. Labor has been (and continues to be) expended in the location, collation and processing of forage samples. These tasks should be completed by the end of this year. Second year funding will be used to analyze these samples in a commercial laboratory next summer. Pending reports on nutrient concentrations, results will be analyzed and final reports generated.

Objective B The hays fed contained the following nutritional composition:

	Alfalfa	**Wheatgrass**
	-----------------% DM basis ----------------	
Crude protein	16.7	8.8
Acid detergent fiber	43.2	40.9
Neutral detergent fiber	51.6	63.1
Calcium	1.33	0.45
Phosphorus	0.24	0.12
Magnesium	0.30	0.14
Potassium	2.76	1.73
Sodium	0.12	0.06
	-----------------ppm, DM basis -----------	
Iron	426	143
Zinc	17	20
Copper	7	2
Manganese	30	29
Molybdenum	3.6	1.3

Liver and kidney weights were affected by the type of hay fed. Steers fed alfalfa had greater liver and kidneys weights than did steers fed wheatgrass hay. This was probably related to the increased nutrient flow to the organs of alfalfa-fed steers. Hot carcass weight did not differ between alfalfa- and wheatgrass hay-fed steers, therefore the increased organ weights were not due simply to increased body mass in the alfalfa-fed steers. Total tissue weight is important to the evaluation of nutrient status as a larger organ can store more minerals and there may be differences in total tissue mineral levels as well as mineral per unit of weight.

So far, liver and kidney copper and zinc concentrations have been analyzed. Hay source influenced liver and kidney copper levels, with concentrations being greater in alfalfa-fed animals. This is related to the increased copper concentrations in the alfalfa hay. Tissue copper levels were not affected by intake level of hay. Within a hay source there was no correlation between copper intake and tissue concentrations. Copper intakes ranged from 14 to 95 mg/d. Liver copper concentrations ranged from 10 to 62 mg/kg dry tissue weight. Liver copper concentrations of less than 20 mg/kg are often considered to be an indication of copper deficiency. Thirteen animals on this studies had liver copper concentrations of less than 20 mg/kg. These thirteen animals had copper intakes encompassing the full range of copper intakes.

Zinc concentrations in liver tended to be affected by hay type even though intakes of zinc were similar between hays groups. The relationship between hay type and tissue zinc concentrations was greater when expressed on a total liver weight basis because of the increased liver weight in alfalfa-fed steers. In kidney, concentrations of zinc did not differ with hay type, but because kidney weight was greater for the alfalfa-fed steers, total kidney zinc was greater in alfalfa-fed steers. This may indicate greater bioavailability of zinc from alfalfa than from grass hay.

Further evaluation of other tissue mineral levels will aid in evaluating bioavailability of minerals. Interrelationships between minerals in the body are complex and tissue concentrations of one mineral can be influenced by that of another. The full complement of analyses will aid in our interpretation of the data. Tissue mineral analysis is scheduled to be completed by October 1999.

Objective C. Samples (384) were submitted to a commercial laboratory for nutrient analysis in May, 1999. Communications with laboratory suggests analyses should be complete by October, 1999. Second year funding will be used to analyze the remaining samples (127) in the summer of 2000. Pending complete reports on nutrient concentrations, results will be analyzed and final reports generated.

Retained Ownership – Three Years of Experience

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Abstract:
Retained ownership of cattle demonstrates that cattle can be source verified back to the cow/calf operation, resulting in benchmarks for weaning, feedlot, carcass and health traits and the subsequent establishment of realistic reachable goals that guide the management of cattle enterprises provided a person is willing to accept the increased risks and associated stress. Ultimately, producers need to start slow, percentage their cattle out at a realistic level that is reflective of their own financial position and their ability to absorb risk. Producers need to understand risk management before they retain ownership of cattle.

Introduction and Justification:
In the future, beef producers need to accumulate a data base that adequately describes the producers cattle and then allows that producer to make necessary genetic and management changes within the operation as needed. The genetic and management changes need to be guided by the operation's goals and the industry's goals throughout this process. These goals must be set based on realistic benchmarks attained by data analysis which includes individual operation data. Effective use of source verification and electronic identification should aid considerably in this endeavor.

Material and Methods:
The Dickinson Research Extension Center (DREC) ranch is located southwest of Manning, North Dakota and pastures cattle in Stark, Dunn and Billings counties and has been in operation since 1905. The current cow herd has approximately a 3/4 Angus X 1/4 Hereford base and currently utilizes Hereford, Angus, Red Angus and Charolais bulls. The cows are utilized for research and managed as three units depending on calving time. Cattle are calved from late February to mid April (spring calving), mid May to mid June (summer calving) and October to early November (fall calving). Cows are allowed to float between calving groups. Spring and summer calves are weaned in late October to mid November, preconditioned for a minimum of 30 days and shipped. Fall calves are weaned in mid April, pastured for the summer and shipped with the spring and summer calves. All calves were marketed through a Kansas feedlot and sold direct to the slaughter house to facilitate the collection of carcass data. The CHAPS and DATALINE™· programs were utilized to establish ongoing benchmarks for weaning, feedlot, carcass and health traits and the subsequent establishment of realistic reachable goals that guide the management of cattle enterprises.

Results and Discussion:
Tables 1-4 present the analyzed production data from the Dickinson Research Extension Center beef herd to illustrate and to increase the understanding of a complete non-segmented beef production system. Producers can establish and maintain a similar professional database by becoming involved with CHAPS 2000. This data allows the establishment of new goals and the adjustment of present goals within the cattle industry to allow for long term survival with the appropriate beef cattle system.

Table 1. Beef Calf Performance for DREC through the North Dakota Beef Cattle Improvement Association CHAPS Program.

Year	Pregnancy Percentage	Calving Percentage	Weaning Percentage	Calf Death Loss	Average Weaning Weight	Average Weaning Age	Pounds Weaned per per Cow Exposed
1996	95.3%	92.9%	91.4%	2.5%	522	207	475
1997	95.3%	94.2%	80.7%	12.4%	542	223	447
1998	95.1%	93.2%	89.3%	5.6%	554	209	495

Table 2. Receiving Value, Final Value and Net Return for DREC Calves Born in 1996, 1997 and 1998.

Year	Sex	N	Receiving Weight	Receiving Value/Hd	Final Weight	Final Value per Calf	Hot Carcass Price/Cwt[a]	Total Net Return per Calf[b]
1996	Steer	159	642	$415	1110	$767	$107.73	$55
1996	Heifer	66	625	$355	1015	$693	$108.74	$82
1997	Steer	127	671	$543	1144	$758	$105.30	$(66)
1997	Heifer	74	626	$487	1103	$714	$104.13	$(76)
1998	Steer	126	707	$494	1204	$817	$105.85	$79
1998	Heifer	54	669	$427	1145	$755	$102.88	$112

a) Includes steers and heifers (8 head) sold as realizers ($51.38/cwt).
b) Includes costs of those steers and heifers that died and those sold as realizers.

Table 3. Feedlot Performance for DREC Calves Born in 1996, 1997 and 1998.

Year	Sex	N	Age at Arrival	Feedlot Average Daily Gain	Days on Feed	Feed Efficiency	Cost of Gain/Cwt	Trucking Cost/Hd
1996	Steer	159	246	3.08	158	6.13	$56.01	$16.41
1996	Heifer	66	249	2.94	147	6.24	$58.04	$15.48
1997	Steer	127	277	3.06	154	6.46	$57.67	$19.01
1997	Heifer	74	269	3.03	160	6.29	$57.38	$19.01
1998	Steer	126	270	3.19	157	6.08	$44.16	$20.00
1998	Heifer	54	286	3.10	154	5.83	$42.33	$19.78

Table 4. Carcass Characteristics for DREC Calves Born in 1996, 1997 and 1998.

Year	Sex	N	Harvest Age	Hot Carcass Weight	Rib Eye Area	Final Yield Grade	Quality Grade	Percent Choice
1996	Steer	159	402	707	12.5	2.3	2.45	57
1996	Heifer	66	397	636	11.7	2.1	2.36	64
1997	Steer	127	429	716	11.6	2.8	2.34	65
1997	Heifer	74	428	682	11.7	2.5	2.45	70
1998	Steer	126	429	769	13.5	2.9	2.28	72
1998	Heifer	54	439	714	12.8	2.8	2.37	61

a) Quality Grade 1=Prime 2=Choice 3=Select 4=Standard; one dark cutter in 1996, three dark cutters in 1997.