Effects of Milk Replacer and Ambient Temperature on Growth Performance of 14-Day-Old Early-Weaned Pigs*

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ABSTRACT : This experiment was conducted in three trials to evaluate optimal ambient temperature for a novel milk replacer feeding system designed for early-weaned pigs, compared to commercial dry diets fed within a conventional hot nursery. A total of 165 PIC genotype pigs were weaned at 13.89±0.7 days of age and allotted to one of two dietary treatments in three trials based on weight and litter origin. Each trial consisted of pigs fed dry diets (DD) and pigs fed milk replacer (MR) which was offered in one of 3 different ambient temperatures. Pigs fed milk replacer were housed in a specialized nursery building in which one half of each pen contained an enclosed hover that was thermostatically maintained at 32℃ while the exterior ambient temperature (where milk was fed) was set at either 17 (trial 1), 24 (trial 2) or 32℃ (trial 3). Pigs fed dry diets with the conventional nursery were maintained at 30℃ for each trial. From d 21 to d 49, all pigs were fed DD within a standardized hot nursery environment. During the first week (d 14-21), pigs fed MR showed increased ADG from 214% to 228% over control pigs fed DD ($p<0.001$), regardless of ambient temperature. As ambient temperature was increased from 17 to 24 to 32℃, ADG of MR-fed pigs was increased by 214%, 220% and 228% over those of pigs fed DD, respectively. ADFIs of MR-fed pigs at 17℃, 24℃, and 32℃ compared with pigs fed DD were increased by 108%, 139% and 164% from d 14 to d 21, respectively. Feed efficiency (G/F) of MR-fed pigs at 17℃, 24℃, and 32℃ compared with pigs fed DD were 199%, 162% and 139% of those of pigs fed DD, respectively. As ambient temperature increased, diarrhea scores showed a slight tendency to increase. The advantage of MR feeding was greater when the ambient temperature was higher, but G/F was impaired with increased ambient temperature. We conclude that ambient temperature within the specialized nursery influenced behavior, MR feed intake, and probably piglet energy expenditure. There were no differences between MR-fed and DD-fed pigs for ADG, ADFI and G/F in the subsequent growth period (d 21 to d 49, $p>0.05$). Maximal advantage of MR feeding was obtained at the intermediate (24℃) ambient temperature during the overall period ($p<0.05$). Results from this experiment indicate that a milk replacer feeding system utilized in the early postweaning period can maximize pig growth performance, and that ADG, ADFI and G/F were affected by different ambient temperatures within MR-fed pigs. The high or low temperatures could not support the maximal growth of pigs fed MR. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 6 : 908-913*)

Key Words : Milk Replacer, Early Weaned Piglet, Growth, Ambient Temperature

INTRODUCTION

Weaning age of piglets has been progressively reduced in the US and some countries in Asia over past two decades in an effort to improve sow productivity, reducing disease transfer from sows and improving piglets growth performance (Odle and Harrell, 1998). Moreover, it has been shown that milk production of sows is not sufficient to support the maximum growth of piglets after two to three weeks post farrowing (Harrell et al., 1993; Azain et al., 1996; Zijlstra et al., 1996).

However, early-weaning has required the development of special management schemes and diets. Consequently, diets with highly digestible and palatable ingredients such as milk products, plasma protein or modified soy protein have been developed for early weaned piglets (Cline, 1991; Hansen et al., 1993; Sohn et al., 1994a, b). Indeed, development of highly digestible and palatable diets has reduced post weaning stress but has not completely eliminated the problem (Odle and Harrell, 1998). In this context, milk replacer and liquid feeding offers great potential as an alternative early weaning management system (Benevenga et al., 1990; Harrell et al., 1993; Azain, 1997; Zijlstra et al., 1996; Azain et al., 1996). Odle and Harrell (1998) reviewed several recent studies with milk replacer and concluded that the growth performance of piglets fed milk replacer could greatly exceed that of littermates fed dry diets or even that of sow-reared controls. In a related study, Zijlstra et al. (1996), described a specialized nursery building in which ambient temperature was maintained at 26℃ and each pen contained an independently heated covered hover in which temperature was maintained above the critical temperature of early weaned piglets (32℃). This segregated-temperature environment (i.e. cool ambient temperature, with heated hovers) was

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hypothesized to limit MR consumption to levels that would prevent nutritional scours. However, little information is available on optimum ambient temperature for this liquid feeding system. Because metabolic rate and feeding behavior may be affected by ambient temperature (Baldwin and Ingram, 1967; Macari et al., 1983; Swiergiel and Ingram, 1986), there is a need to determine the optimum temperature for such a MR feeding system.

This experiment was conducted therefore, in three trials to ascertain an optimal ambient temperature of a novel milk replacer feeding system for early-weaned pigs, compared to pigs weaned on commercial dry diets.

MATERIALS AND METHODS

This experiment was conducted with PIC genotype (PIC 326 (♂) × PIC 231 or 233 (♀)) pigs at the North Carolina State University Swine Research Unit II. The experimental protocol used in this study was approved by the North Carolina State University Animal Care and Use Committee (96-155). A total of 165 pigs were used in three trials. Piglets were weaned at 13.89±0.7 days of age and allotted to one of two dietary treatments in each trial based on weight and litter origin.

1. Dry diet: At weaning control pigs assigned to a three-phase complex dry diets sequence with a conventional hot nursery (table 1). Phase 3 diet was fed after pigs had consumed average 2.3 kg of phase 1 diet followed by 2.3 kg of phase 2 diet.

Table 1. Calculated analysis of diets

	N-14 building		Conventional nursery		
	Milk replacer powder[a]	N-14 starter diet[a]	Phase I diet[b]	Phase II diet[b]	Phase III diet[b]
C. protein, %	25.0	20.0	20.0	20.0	18.0
Lysine, %	2.90	1.50	1.60	1.60	1.10
C. fat, %	4.0	8.0	10.0	9.0	6.8
Ca, %	0.91	0.85	0.80	0.80	0.75
P, %	0.81	0.24	0.70	0.70	0.65
ME, Mcal/kg	3.49	3.58	3.74	3.67	3.31

[a] Supplied by Milk Specialties Company, Dundee, IL, minimum nutrient analysis values.

[b] Supplied by Akey Inc. Lewisburg, Ohio, minimum nutrient analysis values.

2. Milk replacer: Pigs were weaned at d 14 to milk replacer (ICN Milk Replacer, Intensive Care Nursery, Colfax, IL, 61728) for the first 7 d after weaning within the specialized Nursery-14 building (N-14, described below). Milk replacer and N-14 starter dry diet were provided in the pen at the same time. Pigs had no access to water. At d 21, pigs were transferred to a conventional nursery and fed the three complex dry diets sequence (described above).

Because 3 different ambient temperatures were employed, this experiment was conducted in three trials each of which had DD-fed control pigs compared to MR-fed pigs as follows;

Trial 1: 1) 17℃ ambient temperature segregated nursery, fed milk replacer (30 pigs).
2) conventional hot nursery, fed dry diets (30 pigs).

Trial 2: 1) 24℃ ambient temperature segregated nursery, fed milk replacer (23 pigs)
2) conventional hot nursery, fed dry diets (22 pigs).

Trial 3: 1) 32℃ ambient temperature segregated nursery, fed milk replacer (30 pigs)
2) conventional hot nursery, fed dry diets (30 pigs).

At d 21, all pigs were fed dry diets within a standardized hot nursery environment. Until d 49 of age, feed intake and body weight were recorded weekly.

Housing Environments: DD weaned pigs were housed ten per pen (except trial 2, seven or eight per pen) in an environmentally controlled nursery in pens (1.8×1.8 m) with woven-wire flooring. Temperature in the nursery was initially 30℃ and was lowered by 2℃ each week.

Pigs fed MR were housed ten per pen (except trial 2, seven or eight per pen) in the specialized nursery building in raised-deck pens that had metal floors and solid side walls. One half of each pen had a covered hover in which the local temperature was maintained at 32℃ whereas the ambient temperatures were different in each trial as described above. The milk feeder was set outside the hover with nipple feeding system and pigs had *ad libitum* access to feeder. Milk replacer powder was mixed with water and distributed by gravity from mixing compartment to nipple drinkers via plastic tubing. A more detailed description of milk replacer feeding and specialized nursery building was given by Zijlstra et al. (1996).

The calculated analyses of the dry diets and milk replacer are given in table 1. A commercial milk replacer (Milk Specialties Co., Dundee, IL; 160 g milk powder/L water) containing dried whey protein, dried skim milk, dried whey, animal fat, lecithin, vegetable fat, vitamin mix, mineral mix and antibiotics was fed

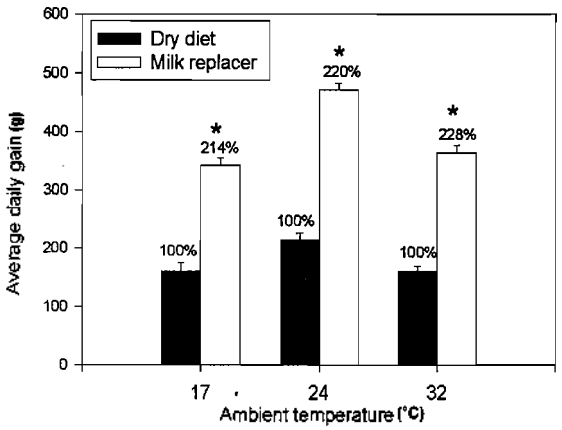
(percentage of ingredients is proprietary). High quality commercial dry diets (Akey Inc. Lewisburg, Ohio) contained the corn, soybean meal, dried skim milk, dried whey, lactose, plasma protein, vegetable and animal fat, dicalcium phosphate, limestone, vitamin mix, mineral mix and antibiotics (percentage of ingredients is proprietary) was fed. Both milk replacer and dry diets met or exceeded nutrient requirements (NRC, 1988)

Pigs were weighed weekly from d 14 to d 49. Feed intake by pigs fed dry diets was measured weekly for each pen. Total milk replacer powder and N-14 starter diet usage was measured. Pigs were observed and a scour incidence score was assigned.

Data were analyzed as a completely randomized design based on weight and litter origin. For ADG (average daily gain) and body weight, the individual pig was used as the experimental unit. Pen means were used as the experimental unit for ADFI (average daily feed intake) and G/F (gain/feed) within the conventional nursery. Differences between treatment in each trial were evaluated by using the T-Test procedure of SAS (1985).

RESULTS

Regardless of the ambient temperatures (17℃, 24℃, and 32℃), MR-fed pigs showed improved ADG. As ambient temperature was increased, ADGs of MR-fed pigs at 17℃, 24℃ and 32℃ (ambient) compared with those of DD-fed pigs were greater by 214%, 220% and 228%, respectively (figure 1).



SEM is symbolized as error bars. * Differs from dry diet, p<0.001

Figure 1. Effect of milk replacer and different ambient temperature on ADG of pigs from day 14-21 days of age

Table 2. Effect of milk replacer and ambient temperature on growth performance of early-weaned pigs in the postweaning period (14-21 days of age)[a]

	Milk replacer	Dry diet
	Trial I	
Ambient temperature	17℃	30℃
Body weight (kg)		
Day 14	5.21 ±0.13	4.94 ±0.17
Day 21	7.60 ±0.19*	6.06 ±0.22
Weight gain (g/day)	342 ±13*	160 ±16
Feed intake (g/day)	326	302
Gain/feed (g/kg)	1,049	530
	Trial II	
Ambient temperature	24℃	30℃
Body weight (kg)		
Day 14	4.83 ±0.16	4.82 ±0.18
Day 21	8.13 ±0.20*	6.32 ±0.20
Weight gain (g/day)	471 ±12*	214 ±12
Feed intake (g/day)	401	288
Gain/feed (g/kg)	1,175	743
	Trial III	
Ambient temperature	32℃	30℃
Body weight (kg)		
Day 14	5.21 ±0.18	5.20 ±0.15
Day 21	7.76 ±0.21*	6.32 ±0.17
Weight gain (g/day)	364 ±12*	160 ±10
Feed intake (g/day)	368	224
Gain/feed (g/kg)	989	714

[a] Values are mean ± standard error.
* Differs from conventional nursery, p<0.001.

Because 3 different groups of MR-fed pigs were compared with each DD weaning, no direct statistical analysis was performed among temperatures; however, the percentage of increases in MR-fed pigs over respective control allowed for general comparisons. Average daily feed intakes of MR-fed pigs were 326 g (289 g of milk powder, 37 g of N-14 starter diet) at 17℃ (ambient), 401 g (358 g of milk powder, 43 g of N-14 starter diet) at 24℃ (ambient), 368 g (342 g of milk powder, 26 g of N-14 starter diet) at 32℃ (ambient), respectively. As ambient temperature was increased, ADFIs of MR weaned pigs at 17℃, 24℃ and 32℃ (ambient) compared with those of DD weaned pigs were increased by 108%, 139% and 164%, respectively. However, by increasing ambient temperature, the relative improvement of G/Fs of MR-fed pigs at 17℃, 24℃, and 32℃ (ambient) compared with those of DD weaned pigs were decreased from 198% to 158% and to 139%, respectively. No statistical analysis was performed on feed intake and feed efficiency, because milk replacer intake of the each pen was not measured.

As ambient temperature increased within the N-14 building, diarrhea scores tended to increase (table 3). But, there was no severe sign of diarrhea or sick pigs

at any temperature. ADG and ADFI of MR-fed pigs compared with those of DD-fed control pigs were improved with increasing ambient temperature, but G/F was impaired.

At d 49, pigs fed milk replacer from d 14 to 21 at 24℃ ambient temperature weighed 11% more ($p<0.05$) than pigs fed dry diets from d 14 to d 21. But, there is no difference between MR weaning and DD weaning for ADG, ADFI and G/F from d 21 to d 49 (table 4; $p>0.05$).

Table 3. Effect of ambient temperature on diarrhea score* of early-weaned pigs fed milk replacer int he postweaning period (14-21 days of age)

Ambient temperature	17℃		24℃		32℃	
Pen No.	1	2	1	2	1	2
Day 15	0	0	0	0	0	0
Day 16	0	0	1	0	1	0
Day 17	0	0	0	0	1	0
Day 18	0	0	1	1	1	1
Day 19	0	0	1	0	2	1
Day 20	1	0	2	1	3	2
Day 21	1	1	3	2	3	2
Total	3/70		12/70		17/70	

* Diarrhea score.
0: No sign of diarrhea, 1:20% of pigs showed diarrhea, 2: 40% of pigs showed diarrhea, 3: 60% of pigs showed diarrhea, 4: 80% of pigs showed diarrhea, 5: 100% of pigs showed diarrhea.

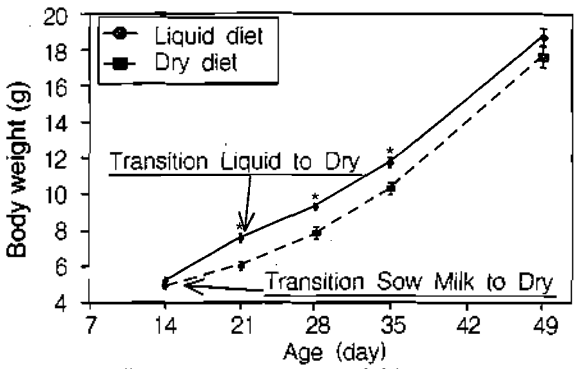
Table 4. Effect of milk replacer and ambient temperature (during 14-21 days of age) on growth performance of early-weaned pigs during the subsequent postweaning period (21-49 days of age)[a]

	Milk replacer	Dry diet
	Trial Ⅰ	
Ambient temperature	17℃	30℃
Day 49 body weight (kg)	18.73±0.42	17.62±0.63
Weight gain (g/day)	398±10	413±16
Feed intake (g/day)	653±14	671±19
Gain/feed (g/kg)	608±8	615±7
	Trial Ⅱ	
Ambient temperature	24℃	30℃
Day 49 body weight (kg)	18.22±0.44*	16.47±0.52
Weight gain (g/day)	360±13	362±15
Feed intake (g/day)	651±15	658±26
Gain/feed (g/kg)	553±18	549±27
	Trial Ⅲ	
Ambient temperature	32℃	30℃
Day 49 body weight (kg)	18.44±0.55	17.41±0.46
Weight gain (g/day)	381±15	396±12
Feed intake (g/day)	656±31	682±14
Gain/feed (g/kg)	582±13	581±9

[a] Values are Mean±standard error.
* Differs from conventional nursery, $p<0.05$.

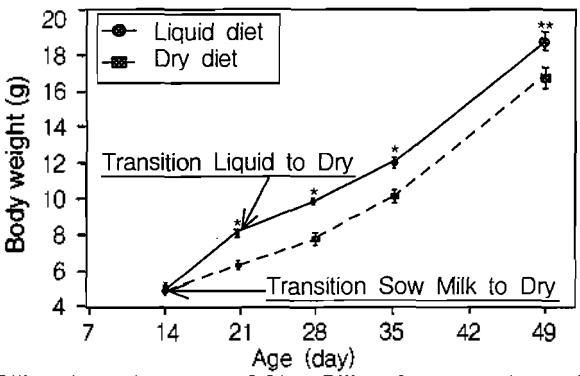
The growth curves of pigs fed MR and DD in each trial are shown in figure 2.

A) Trial Ⅰ, Ambient temperature was 17℃



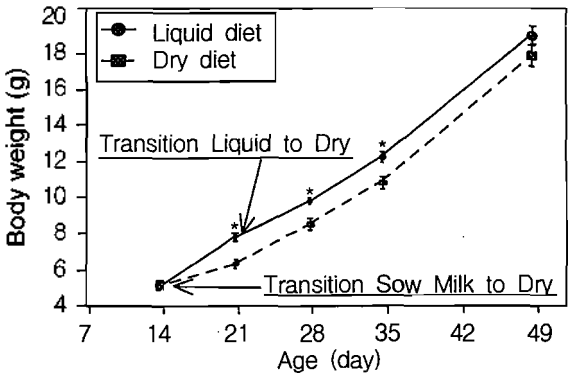
* Differs from dry diet, $p<0.01$

B) Trial Ⅱ, Ambient temperature was 24℃



*Differs from dry diet, $p<0.01$. **Differs from dry diet, $p<0.05$.

C) Trial Ⅲ, Ambient temperature was 32℃



SEM is symbolized as error bar. * Differs from dry diet, $p<0.01$

Figure 2. Mean weekly body weight (kg) of pigs fed either milk replacer at different ambient temperatures or dry diet during day 14-21 days of age

All MR-fed pigs maintained the superior growth rate until 35 d of age, but only at the intermediate temperature (figure 2B), the significant difference in body weight was found at the end of trial (49 d of age). Average daily gain of MR weaned pigs at 24℃ (ambient) was higher than that of DD weaned pigs (table 5; $p<0.05$). But, there is no more differences between MR weaning and DD weaning for ADG, ADFI among three ambient temperatures (table 5; $p>0.05$).

Table 5. Effect of milk replacer and ambient temperature (during 14-21 days of age) on growth performance of early-weaned pigs in the overall postweaning period (14-49 days of age)

	Milk replacer	Dry diet
	Trial Ⅰ	
Ambient temperature	17℃	30℃
Weight gain (g/day)	386±10	362±14
Feed intake (g/day)	588	597
Gain/feed (g/kg)	657	607
	Trial Ⅱ	
Ambient temperature	24℃	30℃
Weight gain (g/day)	382±11*	332±13
Feed intake (g/day)	601	586
Gain/feed (g/kg)	636	567
	Trial Ⅲ	
Ambient temperature	32℃	30℃
Weight gain (g/day)	378±13	349±10
Feed intake (g/day)	599	591
Gain/feed (g/kg)	631	591

[a] Values are Mean±standard error.
* Differs from conventional nursery, $p<0.05$.

DISCUSSION

Pigs fed MR showed improved growth performance over DD-fed pigs, regardless of the ambient temperature. The improved growth performance of pigs fed MR is consistent with previous studies (Benevenga et al., 1990; Harrell et al., 1993; Azain, 1997; Zijlstra et al., 1996; Azain et al., 1996).

Ambient temperature appeared to influence behavior and feed intake. At the low (17℃) ambient temperature, pigs needed to leave the warm hover environment to eat in a cold environment, which presumably influenced meal frequency and/or meal volume. Pigs were usually staying within the heated hover. At the middle (24℃) ambient temperature, pigs did not hesitate to leave the heated hover to eat. Approximately one third of pigs were observed outside of the heated hover at any particular time. At the high (32℃) ambient temperature, pigs moved freely between two areas because the temperatures were identical. Two thirds of pigs could be observed outside of the heated hover, and most feces and urine were observed inside of the hover. These different behaviors influenced pigs' access to milk.

Generally, metabolic rate increases progressively as the ambient temperature falls below a critical temperature (Baldwin and Ingram, 1967) and thus pigs introduced to a cold environment increase their feed intake (Heath and Ingram, 1981). However, in our study, MR-fed pigs always had access to a heated hover where they could obtain enough heat to be comfortable, and therefore it was probably feeding behavior rather than metabolic rate per se that influenced their feed intake and thus growth performance. It has been shown that pigs in a cold environment quickly learn how to get heat when additional heat is available (Baldwin and Ingram, 1967, 1968; Macari et al., 1983; Swiergiel and Ingram, 1986). In this study, more pigs were observed outside of the hover, when the ambient temperature was higher, thus probably had an increased frequency of access to milk replacer.

At the high ambient temperature (32℃), pigs fed MR showed less improved growth performance than pigs at the intermediate temperature (24℃). Since, this study was conducted in three separate trials with pigs having different initial body weight, direct comparison is not appropriate. Nevertheless, it is possible that the high temperature forced pigs to drink more milk and caused a gastrointestinal disorder as observed in high diarrhea score and reduced G/F in trial 3, because the milk replacer was the only source of water in this study. Thus, more study is needed to evaluate the effect of environmental temperature when additional water is available.

Only pigs fed MR at the intermediate temperature could maintain the advantage of MR feeding through the entire trial period. The advantage of MR feeding in low or high temperature had disappeared at 49 d of age. The effect of weaning diets on subsequent growth performance is controversial. Some studies have showed that enriched nursery diets can result in an improved subsequent growth during grower-finisher period (Danielson, 1987; Stairs et al., 1991; Tokach et al., 1995). While others reported no effect of nursery feeding program on subsequent growth rate (Hancock et al., 1994; Whang and Easter, 1994). Harrell et al. (1993) reported a consistent improved growth rate until pigs were 47 d of age when fed a MR diet. Azain (1997) also observed a tendency of increased body weight of pigs fed MR when they were 6 to 7 weeks of age. There was no difference found in 49 d body weight of pigs fed either MR or DD except for pigs at the intermediate temperature in our study, though

pigs fed MR still had a higher body weight at 49 d of age. One possible explanation is the duration of MR feeding. Harrell et al. (1993) fed MR for more than 20 days from 2 to 23 d of age and found a significantly higher body weight at 47 d of age. In our study, pigs fed MR only for one week postweaning. Thus, the effect of duration and long-term effect of MR feeding on subsequent growth performance need to be studied.

Results from this experiment indicate that milk replacer feeding for the early-weaned pigs can help to maximize the growth performance. Furthermore, ADG, ADFI and G/F were affected by different ambient temperatures within MR weaning system utilized herein.

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