Early-life administration of Tonisity Px™ isotonic protein drink to pigs improves farrowing livability and growth to end-nursery

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Introduction

Increases in litter size and concurrent decreases in birth weights have been shown to decrease livability from farrowing to weaning. Similarly, various management approaches or on-farm logistics often result in large spreads in weaning ages. In addition, the small intestine of the newborn piglet goes through tremendous development over the first ten days of life. This period has been identified as a "window of opportunity"[1] for nutritional interventions to improve the development of intestinal structure and the maturation of the immune system which could have lifelong effects. These factors create an opportunity to provide supplemental nutrition in the first days of the piglets' lives to increase livability and growth performance. However, the variables outlined above also have the potential to obscure the results of any intervention if the data is analyzed at a population level. Therefore, the aim of this study was twofold, with the first being to test if an isotonic protein solution (Tonisity Px) provided at days 2 through 8 of age would increase livability through weaning and growth performance to the end of nursery. Secondly, the study examined the effect of Tonisity Px when piglets were stratified into light, medium and heavy birthweights and into three weaning-age peer groups.

Materials and methods

Test ingredient

The test ingredient consisted of an isotonic protein solution (Tonisity Px™), which provides easily-absorbable nutrients (glucose, amino acids, and peptides) and electrolytes that can be used directly by the enterocytes.

Study population and feeding plan

Farrowing: 3862 commercial piglets farrowed from 353 gilts (PureTek genetics) in a 3200 head breed-to-wean farm in Indiana undergoing repopulation were enrolled in the study. Litters were allocated to one of 2 groups, control (Control—1969 piglets) or supplementation with Tonisity Px (TPX—1893 piglets). All piglets were identified at day 2 with two individual ear tags.

Control litters received no liquid nutritional supplementation during the suckling or pre-weaning phase. TPX litters were given 250 ml of 3% Tonisity Px solution on day 2 of age, and from days 3-8 of age TPX litters were given 500 mL of 3% Tonisity Px once daily all in an open pan. Both groups had pelleted creep feed available from day 3 of life to weaning. TPX litters also received 500 ml of 3% Tonisity Px solution three, two, and one days before weaning. Weaning was at 15-37 days.

Nursery: Pigs were moved to two separate nursery sites in Indiana and Illinois at weaning. At each nursery site, all pigs received their standard nursery diet free choice in their feeder and free choice water. TPX pigs also received Tonisity Px solution in open feeding pans on the following schedule: day of arrival → 2 gallons per pen of 3% solution (no feed added), day 1 → 2 gallons per pen of 1.5% solution mixed with feed, day 2 → 2 gallons per pen of 0.75% solution mixed with feed.

Measurements

Pigs were individually weighed at birth, weaning and end of nursery. Pre-weaning mortality was calculated as the number of dead pigs pre-weaning divided by the total number born alive. Nursery mortality rates were not available at the time of this writing. Weight gain data was analyzed by litter and also individually. Weight gain data was further stratified in sub-populations by weaning age (15-18, 19-22, and 23-26 days) and birthweight (< 2.2 lb, 2.2 – 3.5 lb, and > 3.5 lb).

Statistical analysis

Data were analyzed using SAS 9.4 (SAS Inst. Inc., Cary, NC). Mortality was tested using Fisher's Exact test. Weight gain data were assessed for normality with the Kolmogorov-Smirnov test. The individual weight data were not normally distributed, and were therefore analyzed using the Kruskal-Wallis test. Data are presented as medians and 5^{th}-95^{th} percentiles. When stratified by weaning age, the litter data was normally distributed and was analyzed using PROC MIXED, with treatment as a fixed effect, and birth weight, weaning weight and weaning age as covariates in the model, which minimized the variability due to these factors. Results were significant at $P \leq 0.05$ and considered a trend at $P > 0.05$ and $P \leq 0.10$.

Results and discussion

Farrow-to-wean data was received for 3,254 piglets (TPX n =1618, Control n = 1636), representing 353 first-parity litters. Litter-based production data was analyzed. However, the individually-analyzed data was considered to be more relevant to examining the difference in key production metrics for this study which was focused on uncovering the differences that occurred in different age and birthweight sub-populations of pigs, as described in Materials and Methods. This allowed comparison of a much larger number of samples and increased the strength of the analysis. Furthermore, only the individual data could provide the stratification per birth weight. Where relevant, litter-based data is provided for comparison.

Mortality

Pre-weaning mortality in the TPX group was 10.9%, which was significantly lower ($P < 0.001$) than the 14.2% mortality in the Control group. This was a difference of 3.2 percentage points, and represents a 22.8% reduction in preweaning mortality, with the odds ratio for survival at weaning being 1.35 times greater in the TPX group than in the Control group.

This reduction in mortality amounts to the control group losing 63 more pigs compared to the TPX group. Based on the control group of 176 litters, eliminating this loss would amount to a gain of 0.36 pigs weaned/litter, which extrapolates to an extra 0.85 pigs weaned per sow per year (based on 2.36 farrowings per year). The mortality reduction revealed in this study indicates that the micro-enteral nutrition provided during the day 2-8 "window of opportunity" increases piglets' chances of survival to weaning. Furthermore, these results were obtained in healthy pigs, with no disease outbreaks recorded during the trial. It should be noted that all sows were of first parity and thus differences in milking ability were minimized.

Weight gain

Despite the large number of pigs enrolled in the study and the randomization of those pigs into treatment groups, the TPX pigs weighed 0.16 lb more at birth than the control pigs, representing a 4.7% advantage ($P = 0.0001$). The TPX pigs subsequently had higher weaning weights compared to the control group at 13.9 lb vs 13.2 lb ($P = 0.0001$), representing a 5.1% advantage. Piglets in the TPX group gained an average of 0.52 lb/day, which was significantly higher than the control piglets who gained an average of 0.50 lb/day ($P = 0.001$), representing a 2.1% advantage in the TPX group. When analyzed by litter, virtually the same numeric differences were found (0.52 and 0.51 lb), however, they were not statistically significant (data not shown). Similarly, at end of nursery, the TPX piglets outperformed the control pigs, with final individual weights of 55.0 lb vs 53 lb and 55.4 lb vs 54.4 lb as litters; $P < 0.01$). Weight gain in nursery was 42.1 lb vs 40.1 lb based on individual weights and 42.0 lb vs 40.2 lb as litters. Even at the litter analysis level, though, the TPX pigs tended to have a 0.3 lb advantage in weaning weight ($P = 0.07$). The magnitude of this difference increased to 2 lb by the end of nursery, becoming highly significant ($P < 0.01$).

The fact that the *P* values were different for individual and litter data indicates the existence of subpopulations within the data. Such subpopulations may not be detected when analysis is done at a litter level, as this latter is only an average. Weight data were therefore stratified by birth weight and weaning age categories.

Growth performance by birth weight category (Table 1)

Stratifying the growth performance data by birth weight category (< 2.2 lb, 2.2 – 3.5 lb, and > 3.5 lb) removed the significant birthweight differences between treatment groups in the light- and medium-birthweight pigs. The weaning weights were 0.5 lb higher for TPX pigs in the medium birthweight strata ($P < 0.01$) and at the end of nursery, the light and medium birthweight TPX pigs were heavier by 3.5 lb (8.4%; $P = 0.09$) and 1 lb (1.9%; $P < 0.05$), respectively. Similarly, the medium weight TPX pigs showed a significantly higher weight gain pre-weaning and in the nursery phase than control pigs ($P < 0.05$; Table 1). It should be noted that the medium- and light- birthweight pigs accounted for 58% of the study population.

In the heavy-birthweight pigs, although the median birthweight was not different, the TPX pigs had a higher weight range than control pigs. For the heavy birthweight pigs, this translated into a 1 lb numerical advantage for the TPX group. A post-hoc sample size calculation revealed that the 1 lb difference found at the end of nursery would have been statistically significant if 3000 pigs per group had been enrolled. These results demonstrate that Tonisity Px resulted in heavier pigs at the end of nursery across all birthweight ranges.

Growth performance by weaning age category (Table 2)

Due to labor constraints and pig flow, the weaning age of the pigs varied from 15-37 days, which markedly increased the spread of the weaning weights. Performance data was therefore stratified into 3 age categories, namely, early-weaned pigs (15-18 days of age), medium-age-weaned pigs (19-22 days of age) and late weaned pigs (23-26 days of age). Seven pigs over 26 days of age were removed from this analysis. This allowed assessment of whether specific weaning age subgroups reveal any growth trends in relation to the treatment and to make a more sensible estimate of growth performance. For both litter and individual pig analysis, approximately 50% of the pigs in each group were weaned between 19-22 days, with the remaining 50% allocated almost equally to the 15-18 day and 23-26 day weaning age categories (Table 2).

Piglets weaned at 15-18 days of life

For piglets weaned at 15-18 days of life, in the individual analysis, the TPX group had heavier weights from birth to weaning ($P < 0.05$) (Table 2). However, with the exception of a significantly higher birth weight, the litter analysis revealed only numerical differences. Similarly, based on the individual analysis, the pre-weaning weight gains were significantly higher in the TPX group (9.1 lb vs 8.4 lb; $P < 0.01$) but litter analysis showed only a numerical increase. In this weaning age group, there were no significant differences between groups for end-nursery weight and nursery weight gain.

Piglets weaned at 19-22 days of life

In this weaning age category, no significant differences were observed for birth weight, weaning weight or weight gain in the farrowing house (overall or per day) or end-nursery weight as

Table 1: Growth performance of piglets stratified by birthweight[a]

	Light birthweight piglets (<2.2 lb)				Medium birthweight piglets (2.2-3.5 lb)				Heavy birthweight piglets (>3.5 lb)			
Parameter	**Control**	**Tonisity Px**	**P value**	**Change***	**Control**	**Tonisity Px**	**P value**	**Change***	**Control**	**Tonisity Px**	**P value**	**Change***
Birth weight (lb)	2.0 (1.5-2.2)	2.0 (1.3-2.2)	0.67	-	3.0 (2.4-3.5)	3.0 (2.3-3.5)	0.28	-	3.9 (3.5-4.8)	3.9 (3.5-4.9)	0.03#	-
Weaning weight (lb)	10.0 (7.4-13.1)	10.0 (7.4-13.8)	0.17	-	12.5 (8.6-16.8)	13.0 (9.1-17.4)	0.0001	(0.5 lb) 4.0%	14.7 (10.1-19.2)	15 (10.6-20.1)	0.26	(0.3 lb) 2.0%
Weaning weight gain (lb)	8.2 (5.3-11.1)	8.5 (5.8-11.7)	0.14	0.3 lb (4.0%)	9.6 (5.8-13.7)	9.9 (6.3-14.2)	0.0001	(0.3 lb) 3.4%	10.8 (6.2-15)	11.0 (6.6-15.8)	0.33	(0.2 lb) 1.6%
n/% of row total	108/3%	71/2%			921/28%	794/25%			607/19%	745/23%		
Nursery weight (lb)	41.5 (24.5-57.0)	45.0 (30.0-59.0)	0.09	(3.5 lb) 8.4%	52.0 (34.0-65.0)	53.0 (33.0-69.0)	0.02	(1 lb) 1.9%	58.0 (41.0-73.0)	59.0 (38.0-75.0)	0.16	(1 lb) 1.7%
Nursery weight gain (lb)	31.7 (15.4-46.4)	34 (20.2-50.2)	0.14	(2.3 lb) 7.2%	39 (23.7-50.8)	40.4 (21.5-54.2)	0.04	(1.4 lb) 3.4%	43.8 (27.9-57.1)	44.5 (24.6-58)	0.13	(0.7 lb) 1.8%
n/% of row total	80/3%	59/2%			779/29%	641/24%			511/19%	600/23%		

a All weight data is presented as medians with 5-95 percentiles in parentheses
* For the % change, the Control group value was considered the baseline (100%)
\# Although the median is not different between groups, the ranking of the pigs by body weight during the analysis showed that the TPX pigs had significantly higher ranks than the Control pigs.

Table 2: Growth performance of piglets stratified by weaning age[a]

	Early weaned pigs (15-18 days)				Medium age weaned pigs (19-22 days)				Late weaned pigs (23-26 days)			
Parameter	**Control**	**Tonisity Px**	**P value**	**Change ***	**Control**	**Tonisity Px**	**P value**	**Change ***	**Control**	**Tonisity Px**	**P value**	**Change ***
Birth weight (lb)	3.3 (2.0-4.7)	3.6 (2.3-4.8)	0.0001	(0.3 lb) 8.3%	3.3 (2.1-4.5)	3.3 (2.2-4.4)	0.34	0%	3.2 (2.1-4.3)	3.5 (2.3-4.7)	0.0001	(0.3 lb) 10%
Weaning weight (lb)	11.7 (7.8-15.9)	12.6 (8.8-16.7)	0.0001	(0.9 lb) 7.3%	13.7 (9.2-18.2)	13.6 (9.1-17.9)	0.25	(-0.1lb) - 0.6%	14.8 (9.4-19.3)	15.6 (11.1-20.8)	0.0001	(0.8 lb) 5.5%
Weaning weight gain (lb)	8.4 (5.1-11.8)	9.1 (5.7-12.3)	0.0001	(0.7 lb) 7.6%	10.4 (6.3-14.2)	10.2 (6.3-14.0)	0.15	(-0.2lb) -1.3%	11.6 (6.7-15.1)	12.0 (8.0-16.6)	0.001	(0.4 lb) 3.5%
n/% of row total	492/15%	388/12%			871/27%	794/25%			272/8%	430/13%		
Nursery weight (lb)	50.0 (33.0-66.0)	50.0 (32.0-67.0)	0.51	0%	56.0 (37.0-72.0)	56.0 (35.0-73.0)	0.28	0%	54.0 (34.0-67.0)	58.0 (38.0-75.0)	0.0001	(4 lb) 7.4%
Nursery weight gain (lb)	38.2 (24.3-51.5)	37.8 (21.7-53.1)	0.64	(-0.4 lb) - 1.1%	41.6 (25.4-56.1)	42.7 (22.8-56.5)	0.05	(1.1 lb) 2.6%	38.7 (23.1-50)	43.3 (25-57.7)	0.0001	(4.6 lb) 11.9%
n/% of row total	408/15%	319/12%			726/27%	646/24%			235/9%	327/12%		

a All weight data is presented as medians with 5-95 percentiles in parentheses
* For the % change, the Control group value was considered the baseline (100%)

individuals. However, when analyzed individually, the total nursery weight gain was 1.1 lb higher in the TPX group compared to Control ($P < 0.05$; Table 2). This was mirrored by a numerical difference when the data were analyzed per litter. No other differences were observed for this age category, when analyzed by individual or per litter.

Piglets weaned at 23-26 days of life

For the pigs that were older at weaning, the individual analysis revealed a significant difference in the weights of pigs in the TPX pigs compared to Control for birth weight, weaning weight and pre-weaning gain (both overall and per day) ($P < 0.05$; Table 2). However, only numerical differences were observed when the analysis was performed per litter, except for a tendency for higher birth weights for the pigs in the TPX group.

A significant increase in end-nursery weight and overall nursery weight gain was observed for the pigs in the TPX group compared to controls. This was evident for both individual and litter analyses (Table 2). The analyses show a distinct advantage of 4 lb (7.4%) for nursery weight and 4.6 lb (11.9%) for weight gain. For this weaning age the advantage for the TPX group increased from 0.3 lb for birth weight to 0.8 lb for weaning weight to 4 lb for end-nursery weight for individual analysis. These data show that the TPX group outperformed the Control group for the difference even at the litter analysis level and amounted to a statistically significant outcome.

Conclusions

Pre-weaning mortality was reduced by 3.2 percentage points, from 14.2% in the control group to 10.9% in the TPX group. This represents a 22.8% reduction in preweaning mortality. This reduction can be attributed to Tonisity Px and is consistent with results we have seen in multiple previous studies. This is an important benefit at a time where mortality in pig production adds significantly to the losses under tight profit margin conditions. The difference in pre-weaning mortality amounts to 63 pigs that could have been alive in the Control group if they had received Tonisity Px. Those 63 when added to the 62 extra pigs in the TPX group totals an extra 125 pigs from 353 litters. This translates into 0.35 more piglets weaned per litter, and over 1 year, would amount to 0.85 more piglets weaned/sow/year (assuming 2.36 farrowings per year). Assuming that the subsequent mortality in nursery was 3%, i.e., loss of 4 pigs, then an extra 121 pigs out of 3862 (31 pigs/1000) would have finished nursery. At an average nursery weight of 55 lb, the extra 121 pigs would amount to 6655 lb extra weight at the end of nursery.

Despite the spread in weaning ages and birth weights, overall, TPX pigs showed a statistical tendency for increased weaning and nursery weight, total pre-weaning and nursery weight gain, even when analyzed by litter. Stratification of the data into "light", "medium" and "heavy" birthweight piglets clarified the distinct advantages in the TPX group over the control from weaning through the end of nursery. These differences were seen even in the absence of a difference in birth weight. The 8.4% increase in nursery weight in the TPX group for the light birthweight pigs indicates that Tonisity Px allows the piglets to catch up to their growth potential. The medium birthweight pigs, which accounted for ~ 50% of the population (as is typical in most production systems), showed significant weight gain advantages. Furthermore, if the study had contained 3000 pigs per treatment group, the end-nursery weight advantage found in heavy birthweight pigs would also have been significant.

Overall, for the three birthweight categories, at the end of nursery, TPX pigs had 1447.5 lb more body weight (number of pigs in each birthweight category multiplied by the weight advantage (Table 1), distributed as follows: Light birthweight TPX pigs (n = 59) weighed 206.5 lb more overall than Control; medium birthweight TPX pigs (n = 641) weighed 641 lb more; heavy birthweight TPX pigs (n = 600), weighed 600 lb more. At a median weight at nursery of 55 lb, this 1447.5 lb weight difference equals the body weight of an extra 26 nursery pigs.

The growth data from the current study, linked with data from a previous study (data on file) in which mortality was evaluated up until 42 days of age, showed that mortality improvements were achieved equally across light-, medium- and heavy-birthweight pigs. These results indicate that the benefits of administering Tonisity Px to pigs are evident for all weight categories, not only for light birthweight pigs.

Similarly, stratification of pigs by weaning age also revealed better performance for TPX pigs. Piglets weaned between 23-26 days of age weighed 4 lb more at end of nursery and had 4.6 lb higher weight gain in the nursery period. Similarly, piglets in the 19-22 weaning age category gained 1.1 lb more during nursery, without any differences observed for birth weight. These gains amounted to an overall 1308 lb more body weight for the TPX group compared to Controls. Based on a median weight of 55 pounds per pig, this weight difference equals the body weight of 24 nursery pigs.

The data presented in this study provide evidence that sub-populations present in the normal pig production in relation to birth weight and weaning age can behave differently and may be overlooked when analysis is performed only at an overall population level. These data indicate that supplementation early in life has the most effect when the weaning age is higher, and provides evidence that all pigs responded positively to Tonisity Px administration, which adds up to a significant advantage to the producer.

Overall, administration of Tonisity Px from days 2-8 of life and at weaning provide an economically-important advantage to the pork producer by increasing the number of pigs weaned and their subsequent growth performance.

Reference

1. Torow N. et al. The neonatal window of opportunity: setting the stage for life-long host microbial interaction and immune homeostasis. *Journal of Immunology* 2017;198:557-563