Evaluation of three commercial mycotoxin inhibitors added to Vomitoxin (DON) contaminated corn diets for weanling pigs: A Report from the NCCC-042, S-1044, and NCERA-89 Regional Committees on Swine Nutrition and Management[1]

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Summary

A regional study involving 12 experiment stations using a total of 904 weanling pigs in 27 replicates evaluated three commercial mycotoxin inhibitors added to two different vomitoxin (DON) contaminated corn sources. The first corn analyzed 2.0 ppm DON while the second analyzed 7.0 ppm DON. The complete diet, mixed and provided in meal form from one mixing facility, was calculated to contain 1.0 and 3.9 ppm DON, respectively. The companies that produced these mycotoxin inhibitors were asked to recommend their level of product (Defusion®, Integral®, Biofix®) to be added to the diets. The study was blinded from participating companies and investigators to prevent bias. The test period was conducted after a 10 day adjustment period to a common diet. The test period that evaluated these mycotoxin inhibitors was conducted from 10 to 31 day post weaning. The results showed that the high DON corn diet reduced performance responses more severely than diets with low DON contamination. Defusion, added at 10 lb per ton was the most effective mycotoxin inhibitor in our study in both corn sources while the other mycotoxin inhibitors were ineffective. Lighter weight pigs were more severely affected by the DON contaminated diets than pigs of a heavier body weight, but both weight groups responded positively to Defusion. It is questionable if the feeding of a low DON contaminated corn would justify the added expense of the product while it was beneficial when DON was at a high level.

Introduction

At the regional swine nutrition meeting in January 2010, the North Central Coordinating Committee on Swine Nutrition (NCCC-042) recognized the extensive vomitoxin (DON) contamination present in much of the 2009 corn crop in the United States. The contamination was also found to be high in corn by-products such as Dried distillers grains with solubles. The problem was presented to other regional committees (S-1044 and NCERA-89) who had similar concerns. A combination of investigators from these three groups evaluated how our committees could help the

[1]Appreciation is expressed to OARDC Feed Mill Manager Jack Bardall and his crew for procuring the corns, mixing, bagging, wrapping, and transporting the complete diets to the designated stations.

swine producer overcome the DON problem and how to best continue feeding this year's corn crop, particularly since there were no proven mycotoxin inhibitors on the market. It was reported that many pigs completely refused to eat diets containing these DON contaminated corn sources which ultimately could have serious implications on animal health, welfare issues, and economic returns for the swine producer.

Fortunately most of the DON contaminated corn in the U.S was not at a level that seemed to affect cattle or poultry while swine appeared to be the most sensitive to the mycotoxin. Unfortunately, there were no FDA approved mycotoxin inhibitor products available, but there were some products on the market that were reported to be of benefit. However, they were not studied or reported in the literature within the public domain. It was decided to conduct a joint regional project to evaluate three of the major products available, and to share the results with the farm and feed community as quickly as possible. The goal was to evaluate the mycotoxin inhibitor products as to their effectiveness, and how we would recommend feeding the remainder of this year's corn crop. Our desire was to not only complete the study rapidly but also to report the results widely in lay publications for potential use by the swine and feed industry. There were 12 stations that could conduct the study in a timely manner and they and the principal investigators are identified in Table 1.

Procedures followed

Corn from three sources was purchased with different DON levels for conducting the project. The first source was the cleanest source of corn (DON = 1.9 ppm) available. This corn source was fed during the pretrial period for an approximate 10 day period in order to allow the weanling pigs to get started on a common diet (without any mycotoxin inhibitor added) and to overcome the normal post weaning lag in growth and feed intake. The other two corn sources used in the subsequent test diets analyzed 2.0 ppm or 7.0 ppm DON, the former source analyzing somewhat lower than expected. A complete profile of other major mycotoxins analyzed in these corn sources by HPLC determined that DON was the major mycotoxin present (Table 2), that the other mycotoxins, particularly T-2 Toxin and zearalenone were present but at levels below that which would cause problems.

The pretest diet was fed for approximately 10 days and was comprised of dietary feedstuffs normally fed in a phase 1 diet to weanling pigs. Test diets during the following 21 day test period were formulated to utilize as much corn in the diets as possible in order to best test the efficacy of the three selected mycotoxin inhibitor products. Only one diet was fed from the 10 to 31 day period for each treatment group. The companies were contacted and they all agreed to have their products evaluated.

All cooperating stations fed the same pretest diet, used the same corn sources, and used the sane diet mistures (including the pretest diet), mixed at one location (OARDC feed mill, Wooster, OH) and transported to each cooperating station in early February 2010. All diets were formulated to meet or exceed current NRC (1998) swine nutrient requirements (Table 2). Although the products were mixed in some cases a few weeks prior to being fed, most of the studies were done shortly after the diets arrived at the various stations (see Table 1 for staring dates). The three products to be incorporated into the test diets (Defusion®. Integral®, and Biofix Plus®, was added at the expense of corn starch to maintain the same nutrient profile of the remaining dietary constituents. The three commercial mycotoxin inhibitor products were purchased on the open market to ensure that the companies would not be accused of preparing special products for this trial. Each contributing company was given the opportunity to evaluate the corn mycotoxin assay results, the diet formulas that the products were to be added, and to recommend the incorporation level of their product into the test diets with the two corn sources. The amount of products added to the 1.0 ppm diets were (Defusion 10 lb/ton; Integral 4 lb /ton and Biofix Plus 8 lb/ ton), while the amount suggested for the 3.9 ppm diets were (Defusion 10 lb/ton; Integral 6 lb/ton; and Biofix Plus 8 lb/ton). In addition, the treatment and product identification was blinded not only to the company but also to the investigators. Each investigator was asked to collect performance data but to also evaluate other signs, denoting the date and reasons why pigs might be removed from the study. At the completion of the study, each company and investigator was again given the opportunity to review the final results without knowing which treatment represented specific products. All of this was done to ensure that bias would not enter into the conduct of the trial or data interpretation.

The three products evaluated were from the following organizations: BioMin (Biofix Plus®), Akey (Defusion®), and Alltech (Integral®). Vomitoxin consumption has been reported to result in reduced feed intakes, reduce body weight gains, and sub-clinical immune suppression. High levels of vomitoxin may produce intestinal lesions, vomiting, and complete feed refusal. Pig gain and feed intake performance criteria were the measurement traits evaluated in this study. A short explanation of the products and how each product might function in reducing the effects of DON follows:

***Biofix* Plus** (Bio Min) contains yeast cell wall, natural microbials, and diatomaceous earth (clay) which may be effective in reducing DON and other mycotoxins.

Defusion (Akey) is a blend of preservatives, antioxidants, amino acids, and direct-fed microbials which is thought to decrease some of the toxic effects of vomitoxin in pigs.

Integral (Alltech) is a yeast cell wall that has been modified and may serve as an adsorbent of dietary mycotoxins.

The completed trial data was statistically analyzed using conventional SAS analysis of variance procedures. Although pigs were allotted on initial body weight at weaning they were fed a common diet for an approximate 10 day period. Consequently, the weights at the beginning of the test period differed slightly. Thus the 10 day weights were adjusted by covariate analysis (to use a common initial weight within replicate from 10 to 31 day) to ensure that the responses were not affected by differences in weight at the beginning of the test period.

Results

The complete set of data from all stations involving all replicates is reported in Table 3. There were 12 stations that conducted the trial involving a total of 904 pigs. Some replicates contained pigs of an initially lighter or heavier weight at weaning. Therefore six of the lighter weaning weight and seven replicates of the heaviest weight were analyzed independently to see if there were different initial weight responses to the DON contaminated corn sources and the various mycotoxin inhibitors. The performance responses from the 27 replicates are reported in Table 3 while the effect of light or heavy weaning weight pigs are presented in Tables 4 and 5, respectively.

The pretest diet fed for an approximate 10 day period resulted in good performance responses, but two pigs were removed before the product evaluation test period started. Their removal was due to unthriftiness and loss of body weight. In general, the pretest diet that contained a low innate level of DON (0.80 ppm) did not appear to affect pig gains or feed intakes (Table 3).

Feeding the treatment test diets (days 10 to 31 post weaning) clearly resulted in different performance responses to the two different corn sources. Pigs consuming the 7.0 ppm DON corn (diet calculated at 3.9 ppm DON) had reduced pig body weight gains and feed intakes each week of the test period compared to the corn that tested 2.0 ppm DON (diet calculated 1.0 ppm DON). Unfortunately we did not have access to corn without DON contamination and could not make a comparison to such corn. There was no incidence of feed refusal for either of the two test corn sources, but feed intake was reduced when the higher DON contaminated corn was fed. There were a total of five pigs removed from the study. Although unthriftiness of pigs was generally recognized throughout the study it was not severe enough to remove pigs from the trial. Of those pigs removed, the prevailing observation was a decline in body weight, limb immobility, and pneumonia. There was evidence of swollen vulvas when pigs consumed the 3.9 ppm DON diet but this was probably reflective of zearalenone contamination not DON. There was no reported incidence or evidence of intestinal hemorrhages which would be indicative of T-2 Toxin. As expected, the major negative response from DON contamination appeared to result in reduced gain, reduced feed intake, and a general unthriftiness, the latter response was most likely because of the low feed intake.

Comparison of the three commercial mycotoxin inhibitor products for all stations for the 27 replicates is reported in Table 3. For the low Don contaminated corn only Defusion proved to be effective by increasing pig gains and feed intakes during week 1 and 3 of the test period over that of the negative control diet. The effect of the other mycotoxin inhibitors to the diets was statistically similar to the negative control. The overall growth rate and feed intake did not, however, differ significantly for most of the trial for two of the three mycotoxin inhibitors products, but there was an apparent numerical advantage to Defusion. Although this level of DON is reported to be tolerated by the young pig, our results would indicate that its additional expense to diet cost may not be cost effective when a low level ($\leq$ 1 ppm) of DON is fed to weanling pigs.

In contrast, when the high DON corn diets (calculated at 3.9 ppm DON) were fed those pigs consuming the diet with Defusion weighed more at the end of the trial, gained more weight and consumed more feed during each week of the trial than those fed the control or Integral or Biofix Plus mycotoxin inhibitors.

When pigs were evaluated by weaning weight groups they responded to the two corn sources and mycotoxin inhibitor products somewhat differently. The results of the lighter weight pig group (Table 4) indicated that their response to the DON contaminated corn source was more pronounced than the heavier pig group (Table 5). In the light weight group there was a clear benefit to Defusion for both DON contaminated corn sources, whereas there was no response to the other two products. The benefits of Defusion were evident during the initial week of the test period and continued throughout the remainder of the trial. In the heavier pig group the same general trends occurred but the results were not as dramatic as when the lower DON contaminated corn source was fed. Again with the higher DON contaminated corn, Defusion still proved to be the superior mycotoxin inhibitor in both growth rate and feed intake during each week of the trial.

Discussion

Although Defusion was superior in our trial, the corn used in these treatment diets was primarily contaminated with DON and not the other Fusarium molds. How the other mycotoxin inhibitor products used in our study would respond with corn that also contained zearalenone, T-2 Toxin or aflatoxin is unknown. It is unusual that corn mycotoxins are predominated by a single mycotoxin and in some cases the other products might be effective against the other mycotoxins. Because Defusion was also added at a high level, it is not known what a lower dietary inclusion level would produce.

There are several lessons and recommendations that we can make from this study.

1. It is important to analyze for the various mycotoxins present in corn sources or their by-products when fed to swine. The "quick test" done by most elevators is a good starting point for determining the amount of contamination but these tests are not completely reliable and highly variable. Once a large quantity of corn is stored it is a good idea to test the entire bin (several probes) and be analyzed by a recognized laboratory using modern techniques. Be sure to test at various sites in the bin so as not to isolate a "hot spot". Mycotoxin contaminated grains seem to accumulate along the outer edge and in the center of the storage facility.
2. The mycotoxin inhibitors to be used should have public research conducted or research publically presented to ensure that the claims presented are valid and unbiased. The companies being evaluated in this experiment are using this and other research findings that they are conducting to produce better products or to know how to best use their product. These companies are already in the development stage of evaluating newer products.
3. It is possible that the value of mycotoxin inhibitors may vary with different feeding or management conditions. For example we used a dry meal fed diet with weanling pigs. If a swine producer is feeding their feed with water, the enzymes in these or other products might be activated and be more effective than if fed in the dry meal form. The company would be able to address these issues with the swine producer.
4. With the current 2009 corn crop, the grain should be cleaned and fines removed prior to grinding and mixing into swine diets, as most of the mycotoxin will be located in this portion of the grain.
5. Wheat and other grains can also be contaminated during the flowering and early milk or "boot" stage. Consequently, the straw from such crops may be contaminated. There is current evidence that at least some of the current 2010 wheat crop my be contaminated with DON.

6. Stored corn should be dried to a minimum of 14% moisture and aerated frequently so that the mycotoxins will not continue to develop in the bins. When removing grain from the bin, try and remove corn in large batches so as not to isolate “hot spots”.
7. Weanling pigs and reproducing animals should be fed better corns as they are more sensitive to mycotoxins and these production phases will more readily influence pig profitability. Older pigs, particularly grower finisher pigs appear to be able to tolerate higher levels of DON.
8. The use of other grains or ingredients free from mycotoxin contamination should be considered in current diet formulas. But they should be screened for mycotoxins.
9. It is important that when current storage facilities are emptied that they be thoroughly cleaned and a fungicide applied before new corn is added.

Table 1. Project participants and appropriate pig experimental details

Institution	Project leader	Date Started	Weaning age, days	Weaning wt., lb.	Pen spaces ft^2/pig	No. Pigs	Pigs per pen	Feeder holes per pen
Kansas State University	J. Nelssen	3/11/10	21	14.3	3.8	80	5	3
Michigan State	G. Hill	4/23/10	22	17.8	4.8	80	5	3
OARDC, Western Branch	S. Moeller	2/5/10	25	18.1	3.2	80	5	8
Ohio State University	D. Mahan	2/18/10	17	13.7	4.0	80	5	4
Purdue University	L. Adeola	2/22/10	18-23	13.5	9.6	80	5	1
South Dakota State University	C. Hostetler	2/25/10	21	14.5	7.1	48	3	3
University of Arkansas	C. Maxwell	2/16/10	19	14.6	3.9	80	5	2
University of Kentucky	M. Lindemann	4/29/10	17-21	14.5	4.0	64	4	4
University of Illinois	H. Stein	2/24/10	19	11.9	4.0	64	4	5
University of Minnesota	S. Baidoo	2/16/10	18	13.8	6.6	96	3	3
University of Missouri	M. Carlson	4/3/10	21	14.8	4.0	72	3	4
Virginia Tech	M. Estienne	2/18/10	21	17.5	4.8	80	5	4

Table 2. Composition of basal diet (%, as fed basis)

Ingredient	Days of feeding	
	0 – 10 day[a]	10 – 31 day[b,c]
Corn	41.70	55.85
Soybean meal, 48%	14.25	26.00
Soy Protein Concentrate	3.00	7.00
Dried Whey	15.00	0.00
Plasma Protein	6.00	0.00
Blood meal, pork	0.00	1.00
Fishmeal	6.00	0.00
Lysine	0.20	0.20
DL Methionine	0.20	0.20
Corn starch	0.00	1.00
Lactose	10.00	4.00
Fat, choice white grease	1.00	1.00
Dicalcium Phosphate	0.90	1.40
Limestone	0.55	1.00
Trace mineral premix	0.20	0.20
Salt	0.25	0.40
Zinc oxide, 72% Zn	0.25	0.25
Vitamin premix	0.25	0.25
Mecadox	0.25	0.25
Mycotoxin inhibitor[1]	0.00	±

[1]Mycotoxin inhibitor product added at the expense of corn starch. The products were added only in the treatment test diets fed from 10 to 31 days post weaning.

[a]Corn analyzed 1.9 ppm vomitoxin; < 0.50 ppm T-2 toxin; <0.50 ppm zearalenone (analysis by HPLC).

[b]Corn analyzed 2.0 ppm vomitoxin;< 0.50 ppm T-2 toxin; < 0.50 ppm zearalenon (analysis by HPLC).

[c]Corn analyzed 7.0 ppm vomitoxin; < 0.50 ppm T-2 toxin, < 0.50 ppm zearalenone (analysis by HPLC).

Table 3. Effect of mycotoxin inhibitors added to vomitoxin (DON) contaminated corn and fed to weanling pigs

Corn	Test Corn (2.0 ppm DON)				Test Corn (7.0 DON)				
Product:	None	Defusion	Integral	Biofix	None	Defusion	Integral	Biofix	SEM
Added/ton; lb.:	0	10	4	8	0	10	6	8	
Item / Cost/Ton, $:	0	10.00	11.60	22.32	0	10.00	17.40	22.32	
No. of replicates	27	27	27	27	27	27	27	26	-
No. of pigs	113	113	113	113	113	113	113	113	-
No. pigs removed (10-31 day)	1	2	0	0	2	0	0	0	-
Pig weight, lb.									
Weaning	14.7	14.7	14.8	14.7	14.9	14.8	14.8	15.1	0.1
Start of test, 10 d	18.6	18.7	18.8	18.5	18.6	18.8	18.4	19.4	0.2
Final weight, 31 d	39.8^{a}	41.7^{b}	39.4^{a}	39.7^{a}	34.8^{c}	39.7^{d}	34.1^{c}	33.8^{c}	0.4
Pre test period (0 – 10 d)[1]									
Dietary DON level, ppm	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	-
ADG, lb.	0.35	0.40	0.39	0.39	0.38	0.39	0.38	0.39	0.02
ADFI, lb.	0.48	0.50	0.49	0.49	0.49	0.51	0.48	0.51	0.01
Test period (10-31 d)									
Dietary DON level, ppm	1.0	1.0	1.0	1.0	3.9	3.9	3.9	3.9	-
ADG, lb.									
10 – 17 day	0.71^{a}	0.86^{b}	0.73^{a}	0.74^{a}	0.39^{c}	0.73^{d}	0.42^{c}	0.39^{c}	0.02
17 – 24 day	1.04	1.08	0.97	0.99	0.83^{c}	1.03^{d}	0.77^{c}	0.76^{c}	0.03
24 – 31 day	1.31^{a}	1.42^{b}	1.35^{a}	1.36^{a}	1.11^{c}	1.33^{d}	1.07^{c}	1.06^{c}	0.04
10 – 31 day	1.02	1.09	0.99	1.03	0.75^{c}	1.01^{d}	0.80^{c}	0.74^{c}	0.11
ADFI									
10 – 17 day	0.99^{a}	1.13^{b}	1.01^{a}	1.07^{a,b}	0.71^{c}	0.99^{d}	0.69^{c}	0.70^{c}	0.03
17 – 24 day	1.52	1.57	1.41	1.45	1.15^{c}	1.45^{d}	1.08^{c}	1.04^{c}	0.04
24 – 31 day	1.95^{a}	2.13^{b}	1.94^{a}	1.99^{a}	1.64^{c}	1.98^{d}	1.56^{c}	1.61^{c}	0.05
10 – 31 day	1.50^{a}	1.60^{b}	1.46^{a}	1.52^{a}	1.19^{c}	1.49^{d}	1.16^{c}	1.16^{c}	0.03
Feed/Gain 10 – 31 d	1.48	1.46	1.46	1.49	1.60^{c}	1.46^{d}	1.54^{c}	1.64^{c}	0.05

$^{a, b}$ Means with different superscripts on the 1.0 ppm diet differed ($P < 0.05$).

$^{c, d}$ Means with different superscripts on the 3.9 ppm diet differed ($P < 0.05$).

[1] The pretest period involved feeding a common diet without the mycotoxin inhibitor products added. A total of 2 pigs were removed during the pre test period because of unthriftiness.

Table 4. Effect of mycotoxin inhibitor products added to vomitoxin (DON) contaminated corn fed to light weight weanling pigs

Item	Corn	Test Corn (2.0 ppm DON)				Test Corn (7.0 ppm DON)				SEM
	Product:	None	Defusion	Integral	Biofix	None	Defusion	integral	Biofix	
	Added/ton; lb.:	0	10	4	8	0	10	6	8	
No. of replicates		6	6	6	6	6	6	6	6	-
No. of pigs		29	29	29	29	29	29	29	29	-
Weaning weight, lb		12.4	12.5	12.5	12.3	12.5	12.4	12.5	12.4	
Test period (10 – 31 d)										
Dietary DON level, ppm		1.0	1.0	1.0	1.0	3.9	3.9	3.9	3.9	-
Pig weight, 10 d		15.6	15.5	15.8	15.2	15.4	15.5	15.8	15.3	0.3
Final weight, 31 d		34.3^{a}	37.0^{b}	34.5^{a}	33.6^{a}	28.3^{c}	33.3^{d}	28.2^{c}	27.6^{c}	0.9
ADG, lb.										
10 – 17 day		0.60^{a}	0.78^{b}	0.60^{a}	0.66^{a}	0.32^{c}	0.60^{d}	0.31^{c}	0.29^{c}	0.03
17 – 24 day		0.87^{a}	1.06^{b}	0.87^{a}	0.89^{a}	0.62^{c}	0.88^{d}	0.65^{c}	0.60^{c}	0.05
24 – 31 day		1.23	1.31	1.18	1.13	0.94^{c}	1.12^{d}	0.95^{c}	0.88^{c}	0.04
10 – 31 day		0.88	1.00	0.87	0.89	0.60^{c}	0.87^{d}	0.62^{c}	0.60^{c}	0.04
ADFI, lb.										
10 – 17 day		0.79^{a}	0.99^{b}	0.82^{a}	0.90^{a}	0.67^{c}	0.80^{d}	0.60^{c}	0.55^{c}	0.05
17 – 24 day		1.31	1.40	1.19	1.27	0.86^{c}	1.28^{d}	0.88^{c}	0.93^{c}	0.05
24 – 31 day		1.74	1.76	1.73	1.69	1.35^{c}	1.69^{d}	1.41^{c}	1.55^{c}	0.05
10 – 31 day		1.39	1.44	1.33	1.41	1.04^{c}	1.39^{d}	1.08^{c}	1.16^{c}	0.06
Feed/gain ratio										
10 – 31 day		1.59	1.44	1.56	1.62	1.77^{c}	1.58^{d}	1.81^{c}	2.08^{e}	0.08

[a, b] Means within the 4.0 DON corn treatment groups differed ($P < 0.05$).

[c, d,e] Means within the 7.0 DON corn treatment groups differed ($P < 0.05$).

Table 5. Effect of mycotoxin inhibitors added to vomitoxin (DON) contaminated corn and fed to heavy weight weanling pigs

Item	Corn	Test Corn (2.0 ppm DON)				Test Corn (7.0 ppm DON)				
	Product:	None	Defusion	Integral	Biofix	None	Defusion	Integral	Biofix	SEM
	Added/ton; lb.:	0	10	4	8	0	10	6	8	
No. of replicates		7	7	7	7	7	7	7	7	-
No. of pigs		33	33	33	33	33	33	33	33	-
Weaning weight, lb		17.2	17.2	17.2	17.3	17.2	17.5	17.4	17.1	
Test period (10 – 31 day)										
Dietary DON level, ppm		1.0	1.0	1.0	1.0	3.9	3.9	3.9	3.9	-
Pig weight, lb. 10 d		21.3	21.6	21.6	21.2	21.5	22.0	21.5	21.5	0.5
Final weight, lb. 31 d		45.1	46.2	44.5	44.5	39.5[c]	44.5[d]	39.9[c]	39.3[c]	1.40
ADG, lb.										
10 – 17 day		0.85	0.91	0.80	0.80	0.44[c]	0.78[d]	0.60[c]	0.44[c]	0.05
17 – 24 day		1.12	1.05	1.07	1.01	0.90[c]	1.13[d]	0.86[c]	0.93[c]	0.07
24 – 31 day		1.41	1.53	1.41	1.52	1.23	1.30	1.18	1.18	0.08
10 – 31 day		1.08	1.11	1.04	1.07	0.83[c]	1.03[d]	0.86[c]	0.82[c]	0.05
ADFI, lb.										
10 – 17 day		1.13	1.18	1.16	1.15	0.75[c]	1.02[d]	0.82[c]	0.80[c]	0.05
17 – 24 day		1.62	1.67	1.60	1.62	1.17[c]	1.61[d]	1.30[c]	1.26[c]	0.08
24 – 31 day		2.20	2.30	2.08	2.26	1.94	2.01	1.83	1.74	0.11
10 – 31 day		1.61	1.63	1.55	1.61	1.29[c]	1.51[d]	1.34[c]	1.22[c]	0.08
Feed/gain ratio										
10 – 31 day		1.46	1.48	1.50	1.49	1.53	1.48	1.47	1.50	0.03

[c, d] Means within the 7.0 DON corn treatment groups differed ($P < 0.05$).