The Influence of MOS on Sow and Piglet Performance

PEER REVIEWED

Mannanoligosaccharides (MOS) are complex carbohydrates derived from the cell wall of selected strains of the yeast *Saccharomyces cerevisiae*. The primary effects of MOS on the performance of animals results from several clearly defined modes of action:

- Agglutination and attachment of certain pathogenic bacteria, such as *E. coli* and *Salmonella*, by MOS, thus improving the microbial status of the gastro-intestinal tract
- Modulation of the immune system
- Improved intestinal function or gut health
- Better nutrient provision and utilisation for production purposes since less nutrients are needed for the activation of the immune system.

All of these effects result in improved performance, and extensive reviews of the scientific literature by Miguel *et al*. (2004) and Rosen (2006) have shown that both growth rate and feed efficiency have been improved when the MOS product Bio-Mos® (MOS; Alltech Inc.) was provided in the diets of piglets post-weaning and during the growing-finishing period.

The purpose of this paper is to review all available sow studies for the response to MOS and to suggest possible modes of action for any positive response obtained.

Description of Trials

A description of the trials carried out is presented in Table 1.

Study No	Country	Nos of sows	Bio-Mos application		Litter size			Piglet weight		Colostrum quality
			Gestation	Lactation	Total born	Born alive	Weaned	Birth weight	Weaning weight	
1	USA	24	5 g/d (14d)	5 g/d (21d)			✓		✓	✓
2	USA	1028	2 kg/t (21d)	1 kg/t (21d)	✓	✓	✓	✓	✓	✓
3	USA	318	5 g/d (21d)	5 g/d (21d)	✓	✓	✓	✓	✓	✓
4	Croatia	221	2 kg/t (14d)	2 kg/t		✓	✓	✓	✓	
5	Italy	480	1.5 kg/t (60d)	1.5 kg/t		✓	✓	✓	✓	
6	Argentina	334	1.5 kg/t (25d)	1.0 kg/t (16d)			✓	✓	✓	
7	Spain	80	2 kg/t (14d)	1 kg/t (28d)	✓	✓	✓	✓	✓	✓
8	Hungay	81	2 kg/t (42d)	1 kg/t (28d)		✓	✓	✓	✓	
9	France	52	4 g/d (84d)	4 g/d (21d)	✓	✓	✓	✓	✓	✓
10	Canada	48	1 kg/t (throughout gest.)	1 kg/t (21d)	✓	✓	✓	✓	✓	✓
11	Mexico	270	1.5 kg/t (21d)	1.5 kg/t (21d)		✓	✓	✓	✓	
12	Poland	30	8 g/d (30d)	8 g/d (21 d)		✓	✓	✓	✓	✓
	Poland	30	8 g/d (30d)	8 g/d (21 d)		✓	✓	✓	✓	✓

Table 1. MOS in sow diets: Description of studies and measurements

1. Newman and Newman (2001)
2. O'Quinn *et al*. (2001)
3. Maxwell *et al*. (2003)
4. Barac *et al*. (2002)
5. Spring *et al*. (2003)
6. Fetcheverry and Soriano (2003)
7. Medel *et al*. (2004)
8. Babinsky (2005)
9. Le Dividich *et al*. (2009)
10. Le Dividich *et al*. (2009)
11. Gomez and Landeau (2009)
12. 12) Czech *et al*. (2009)

Key to trials:

In total, 12 trials have been carried out: four studies have been conducted at universities / research stations, whereas the remainder were carried out as commercial trials, often under the supervision of trained experimental technicians. Litter size was not recorded in Trial 1 and in Trial 6; only the number of piglets weaned was recorded. Trial 1 used only 24 sows and this is too few to support confidence in the data, especially in relation to litter size. The birth weight and weaning weight of the piglets were recorded in all trials with the exception of Trial 1, where only weaning weight was recorded. In four studies, colostrum samples were taken and analysed for their content of immunoglobulin: IgA, IgG and IgM.

Effects on Litter Size and Pre-weaning Mortality

The effects of MOS in sow diets on litter size are presented in Table 2. There was no significant ($p>0.05$) effect of the inclusion of MOS in the diet of the sow on the number of piglets born alive compared with the control animals: 11.24 (±1.33) vs 11.14 (±1.18), respectively.

The number of piglets weaned per litter was numerically higher when sows were fed MOS: 10.11 (±1.09) vs 9.67 (±0.74), respectively, but the overall difference was non-significant ($p<0.05$). The increase in the number of piglets weaned per litter when adjusted for differences in the number born alive was 0.32 (±0.34) (range 0.0 to 1.27).

The increase in the number of piglets weaned when sows were fed MOS resulted from a 21.0 % decrease in pre-weaning mortality: 11.5 (±1.85) vs 9.13 (±1.67) %. The effect was cumulative and independent of litter size (Figure 1).

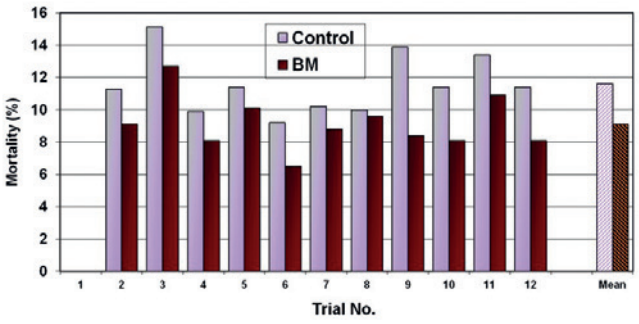

Figure 1.The effect of MOS on pre-weaning mortality

Trial No.		Control	BM
1	Total born		
	Born alive		
	Weaned		
	Mortality (%)		
2	Total born	-	-
	Born alive	9.96	9.78
	Weaned	8.84	8.89
	Mortality (%)	11.27	9.09*
3	Total born	12.47	12.13
	Born alive	11.00	10.76
	Weaned	9.34	9.39
	Mortality (%)	15.10	12.70
4	Total born	-	-
	Born alive	10.53	10.08
	Weaned	9.49	9.26
	Mortality (%)	9.88	8.13
5	Total born	-	-
	Born alive	10.49	10.66
	Weaned	9.29	9.59
	Mortality (%)	11.41	10.08
6	Total born	-	-
	Born alive	-	-
	Weaned	10.10	10.90
	Mortality (%)	9.20	6.50
7	Total born	11.20	11.90
	Born alive	9.80	10.30
	Weaned	8.80	9.40
	Mortality (%)	10.20	8.80
8	Total born	-	-
	Born alive	10.55	10.95
	Weaned	9.50	9.90
	Mortality (%)	10.00	9.60
9	Total born	13.47	12.59
	Born alive	12.99	11.85
	Weaned	9.96	10.09
	Mortality (%)	13.90	8.40
10	Total born	13.64	14.84
	Born alive	12.72	13.58
	Weaned	10.64	11.69
	Mortality (%)	11.40	8.10
11	Total born	-	-
	Born alive	10.76	10.93
	Weaned	9.28	9.74
	Mortality (%)	13.44	10.88
12	Total born	-	-
	Born alive	12.64	13.47
	Weaned	11.20	12.38
	Mortality (%)	11.39	8.09
Mean	**Total born**		
	Born alive	**11.14 (±1.18)**	**11.24 (±1.33)**
	Weaned	**9.67 (±0.76)**	**10.11 (±1.09)**
	Mortality (%)	**11.56 (±1.85)**	**9.13 (±1.67)**

* Denotes statistical difference ($p<0.05$)

Table 2. The effects of MOS on litter size and pre-weaning mortality

Effect on Birth Weight and Weaning Weight

The effect of MOS in the diet of the sow on piglet birth weight and weaning weight is presented in Table 3.

The inclusion of MOS in the diet of the sow resulted in the mean birth weight increasing from 1.46 (±0.11) to 1.52 (±0.11) kg ($p>0.05$). Indeed, in several of the individual studies, this difference was significant ($p<0.05$). This increase in birth weight is noteworthy, and one interpretation may be that nutrient availability is increased in the MOS-fed sows, which results in greater foetal and tissue accretion and hence piglet birth weight.

Similar to birth weight, the inclusion of MOS resulted in an increase in mean weaning weight across all trials: 7.17 (±1.28) vs 6.87 (±1.25) kg (Figure 2); and again, for several of the trials, this difference was significant. When corrected for difference in birth weight, the increase in weaning weight was 0.26 (±0.23) kg per piglet.

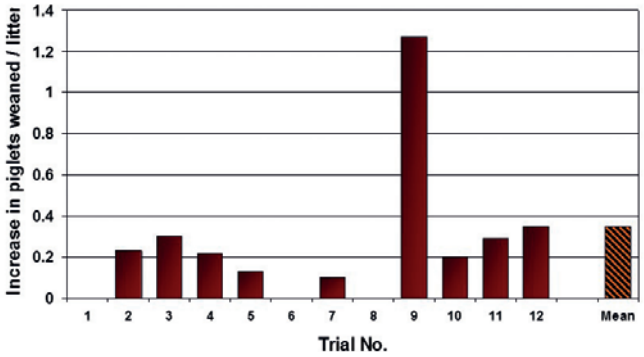

Figure 2.The effect of MOS on the weaning weight of piglets

Study		Control	BM
1	Birth weight (kg)		
	Weaning weight (kg)	6.37	7.61*
2	Birth weight (kg)	1.66	1.70
	Weaning weight (kg)	5.47	5.80*
3	Birth weight (kg)	1.38	1.41
	Weaning weight (kg)	5.63	5.77
4	Birth weight (kg)	1.36	1.42
	Weaning weight (kg)	6.16	6.91
5	Birth weight (kg)	1.56	1.58
	Weaning weight (kg)	8.61	8.71
6	Birth weight (kg)		
	Weaning weight (kg)	6.40	6.80
7	Birth weight (kg)	1.55	1.68
	Weaning weight (kg)	6.53	7.13*
8	Birth weight (kg)	1.31	1.50
	Weaning weight (kg)	9.14	9.66*
9	Birth weight (kg)	1.37	1.41
	Weaning weight (kg)	5.94	6.13
10	Birth weight (kg)	1.45	1.48
	Weaning weight (kg)	6.73	6.83
11	Birth weight (kg)	1.40	1.42
	Weaning weight (kg)	6.67	6.97
12a	Birth weight (kg)	1.61	1.57
	Weaning weight (kg)	7.99	7.82
12b	Birth weight (kg)	1.48	1.57
	Weaning weight (kg)	7.71	7.76
Mean	**Birth weight (kg)**	**1.46** (±0.11)	**1.52** (±0.11)
	Weaning weight (kg)	**6.87** (±1.25)	**7.17** (±1.25)

* Denotes statistical difference ($p<0.05$)

Table 3. The effect of MOS on piglet birth weight and weaning weight

Colostrum Quality and Quantity

It has been hypothesised that the improvement in the weaning weight, and hence growth rate, of the piglets from sows fed MOS may result from an improvement in colostrum quality. Colostrum samples were therefore taken within the first 24 hours of farrowing and the concentration of IgA, IgG and IgM analysed (Table 4). Indeed, in one study (Le Dividich *et al.*, 2009), Study 9/10, the rate of colostrum production was also measured.

Within several of the studies there were significant increases ($p<0.05$) in individual Ig concentration. One study reported a significant increase in IgA and four studies indicated significant increases in IgG and IgM. Across all trials where colostrum composition was measured, there was a 5.8, 8.1 and 15.1% increase in the concentration of IgA,

IgG and IgM, respectively, in the colostrum within the first 24 hours post-farrowing for sows fed MOS compared with control-fed sows.

One interesting feature of Trials 9 and 10 by Le Dividich

Study No	No. of Sows		Units	IgA		IgG		IgM	
	Control	BM		Control	BM	Control	BM	Control	BM
1	12	12	mg/dl	667	629	3565	4215*	316	440*
2	42	48	mg/dl	1097	1178	4842	5853*	241	273*
3	15	15	ng/ml	986	967	3252	3208	309	344
9/10	10	10	mg/dl	174	219*	1134	1095	150	149
12 (a)	15	15	ng/ml	11.77	11.91	79.26	87.33*	6.88	7.82*
12 (b)	10	20	ng/ml	12.21	13.17	84.94	91.63*	7.43	8.42*

* Denotes statistical significance ($p<0.05$)

Table 4. The effect of Bio-Mos on colostrum quality

et al. (2009) was that in addition to collecting colostrum, the growth rate of the piglets within the first 24 hours post-birth was recorded, and since litter size was known, the production of colostrum was calculated (Table 5). Colostrum production was significantly increased ($p<0.05$) in the first 24 hours post-partum when MOS was included in the diet of the sows, by 16.6 % and 13.1 % in the French and Canadian trials, respectively. This significant increase in colostrum production resulted in a significant improvement in growth rate in the 24-h period post-birth. However, the improvement in growth rate may not solely be associated with the increase in colostral immunoglobulins, but also with the additional nutrient supply, as well as other metabolic stimulants at the higher colostrum intake. However, other nutrients present in colostrum were not analysed.

	France		Canada		
	Control	BM	Control	BM	P
Piglet growth (0-24 h) (g)	83	123	138	164	0,02
Colostrum consumed/piglet (g)	304	362	364	385	0,04
Colostrum (l/day)	3,36	3,92	4,28	4,84	0,02

Table 5. The influence of the inclusion of MOS on colostrum production and piglet growth rate (Le Dividich *et al*., 2009)

Other Effects

Few studies have measured the subsequent or long-term effects on reproduction. However, in the study of Quinn *et al*. (2001) there was a reduction in the weaning to oestrus interval from 7.27 to 5.20 days ($p<0.01$) when MOS was included in the diet during both gestation and lactation. In addition, on rejoining the breeding herd, 88 % of the MOS-supplemented sows returned to oestrus compared with only 77.6 % of the control sows. Maxwell *et al*. (2003) found a 0.5-day reduction in the wean-oestrus period from 6.41 to 5.96 days.

In terms of piglet performance, the benefits of MOS in the sow diet may extend beyond weaning. In the studies of Medel et al. (2004), MOS had a greater effect on the performance of the piglets post-weaning when MOS was added to the sow diet than when added to the weaner feed. In the post-weaning period (28-60 days of age), the growth rate of piglets from sows fed MOS was 363 g/day compared to 339 g/day for those from control sows. This 7.1 % increase in growth rate of piglets post-weaning compares with a 4.2 % increase reported by Miguel *et al*. (2004) for a review of the

extensive data available. Feed conversion efficiency was also enhanced from 1.50 to 1.39 g/g, respectively. This suggests a 'carry-over' effect into the period post-weaning for piglets from sows fed MOS.

Economic Benefits

Based on the mean responses from the 12 studies investigated and the various costs of production, as well as the cost of MOS, it has been possible to calculate the cost-effectiveness of its inclusion in sow rations.

A number of assumptions have been made which have been based on sound scientific principles.

1. Cost of MOS inclusion

The recommended MOS inclusion rate is 1 kg/ton during both lactation and gestation.

- Sow consumes 1.2 t of feed per year. Therefore MOS inclusion = 1.2 kg
- Cost of MOS = $5.50/kg Total cost of inclusion = **$6.60/sow/year**

2. Effect on litter size

- Across all trials the improvement on litter size was 0.32 / litter
- If we assume 2.4 litters/sow/year, this equates to an extra **0.77 piglet/sow/year**
- Value of piglet at weaning = $40. Therefore value of extra piglets = **$30.8/sow/year**

3. Effect of enhanced piglet weaning weight

It is generally recognised that for each additional 0.1 kg in piglet weaning weight the animal takes 1 day less to slaughter (Wolter *et al*., 2001; Smith *et al*., 2007).

- Across all trials the mean improvement in weaning weight was 0.30 kg/pig.
- Thus, piglets take 3 days less to achieve slaughter weight.
- This represents 3 days less feed for maintenance; equivalent to 1 kg of feed per day = 3 kg of feed @ $0.2/kg = $0.60 / pig
- If 20 piglets are sold per sow per year = $0.6x20 = $12/sow/year

4. Reduced overall costs

- Pigs take 3 days less to slaughter and this represents 3 days less production costs @ $0.1/kg = $0.3/pig = **$6/sow/year ($0.30x20)**

5. Net return

- The overall benefits of MOS in the sow diet = $30.8 + $12 + $6 = $48.8/year
- The cost of MOS inclusion in the sow diet is $6.6/sow/year
- Thus, the net return per sow per year is: $48.8 - $6.6 = $42.2/sow/year
- The calculated return over investment (ROI) = $48.8÷6.6 = **7.4 : 1**

These calculations do not consider any additional benefits associated with a reduction in the period between weaning and oestrus.

Overall Conclusions

The results of the review show that when MOS is included in the diet of the sow during gestation and lactation, the following responses were recorded:

- An extra 0.32 piglets weaned per litter = 0.77 piglets/sow/year
- An improvement in piglet weaning weight of 0.30 kg
- An increase in the concentration of immunoglobulin in colostrum
- An increase in colostrum production during the first 24 hours post-partum
- Improved piglet growth rate in the first 24 hours of life
- A 'carry-over' effect with higher performance of piglets post-weaning
- Reduced wean-oestrus period = fewer empty days = more litters born
- A very cost-effective response with an ROI of 7.4:1

These responses may be associated with several of the proposed modes of action:

- Better microbial status of the gastro-intestinal tract
- Better prevention of immuno-suppression associated with infection
- Better immune and health status of the sows and her piglets
- Better maintenance of gut integrity and function = better gut environment
- Reduced acute-phase protein production = more nutrients available for production purposes (Che *et al*., 2009)
- Better utilisation and accretion of nutrients
- Improved birth weight = better piglet growth = better subsequent performance
- Enhanced immunoglobulin intake in early life = better protection.

The responses to MOS in sow diets are therefore constant, with considerable advantages for both sow and piglet performance and hence profitability.

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