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Short Communication

Effects of functional additives on production and economic performance of heavy and light bodyweights of nursery piglets

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Abstract

The aim of this study was to evaluate the effects of seven different types of additives on the production performance and economic benefits of piglets at the nursery stage. A total of 2806 piglets, at ~21 days of age, were selected and divided into a high-bodyweight (H) group (> 6.5 kg) and a low-bodyweight (L) group (<6.0 kg) based on the weaned bodyweight (BW). Each group was further subdivided into seven additive groups and a control group. The control group was provided with basal diet, while the additive groups received the corresponding functional additives for either 15 or 30 d. Data collection continued until the end of the nursery stage (on the 45th day of the trial, at 70 d of age). Any single additive did not substantially improve the gained BW in nursery piglets. Overall, sex did not result in any BW differences at any time points. Supplementing feed with additives for 30 d led to better results in terms of production performance and economics for both H and L groups compared to 15 d, particularly with the fermented traditional Chinese medicine (additive VI). In comparison to the control group, the beneficial differences in the H group was more than double that observed in the L group. In summary, supplementing with functional additives for 30 d has potential to improve the production performance and economic benefits of nursery piglets, especially high-bodyweight piglets.

Keywords: additives, economic benefits, feeding time, fermented traditional Chinese medicine, piglets
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In modern, large-scale pig farms, early weaning of piglets is an important strategy to improve the reproductive performance of sows (Blavi *et al*., 2021). However, the transition from milk to solid feed during weaning often leads to stress and intestinal dysfunction in piglets, impacting nutrient intake and absorption, consequently reducing growth performance (Liu *et al*., 2021; Wei *et al*., 2021). Numerous studies have demonstrated that specific feed additives (referred to as functional additives in this study), such as probiotics, bacteriophages, vitamins, organic acids, plant extracts, and trace elements (such as copper and zinc), can contribute to enhancing the production performance and intestinal health of weaned piglets (Han *et al*., 2016; Upadhaya & Kim, 2021). Nonetheless, there is a lack of large-scale field trials simultaneously verifying the impacts of various types of feed additives.

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Previous studies have shown that the subsequent growth performance of light-bodyweight (L) weaned pigs tended to lag behind that of normal and heavy ones (Mahan *et al.*, 1991; Collins *et al.*, 2017). In China, most farms prefer to separately breed and manage the heavy-bodyweight (H)/(L) weaned piglets in a same house. The growth performance of these separated pigs during the nursery stage has been rarely reported. Therefore, the purpose of this study was to investigate the optimal types and duration of functional additives that effectively enhanced the production and economic performance of weaned piglets with H and L under field conditions. The findings of this study could be helpful to do the management practices for weaned piglets in large-scale pig farming operations, potentially enhancing overall productivity and economic outcomes.

The experimental procedures were approved by the Technology Ethics Committee of Dezhou University (DZU/IACUC No. 17-2022).

This study evaluated seven different types of functional additives:

I Nutritional supplements (Components: Vitamin C, Vitamin E, Vitamin B3, taurine, citric acid, bile acid. self-developed product; Dezhou, China);

II Compound probiotics (Components: Probiotics, fermented *Astragalus memeranaceus* (Fisch.), yeast polysaccharide, yeast trace elements, metallothionein. Shandong Baolai-Leelai Bio-Industrial Group; Qingdao, China);

III Chinese herbal extracts (Components: *Codonopsis pilosula* (Franch.) Nannf., *Atractylodes macrocephala* Koidz. (fried), Massa Medicata Fermentata, *Dioscorea polystachya* Turczaninow, *Glycyrrhiza uralensis* Fisch. (stir-baked with honey), *Astragalus membranaceus* (Fisch.), *Saposhnikovia divaricata* (Trucz.) Schischk., etc. Jizhong Pharmaceutical Group; Baoding, China);

IV Antibiotic (Components: compound amoxicillin powder, tylvalosin tartrate premix. Tianjin Ringpu Bio-Technology Co., Ltd; Tianjin, China);

V Premix for Poultry and Livestock (Components: Vitamin A, Vitamin D3, Vitamin E, Vitamin K3, Vitamin B1, Vitamin B2, Vitamin B6, Vitamin B12, Vitamin C, biotin, folic acid, niacin, calcium pantothenate. Bayer (Sichuan) Animal Health Co., Ltd; Chengdu, China);

VI Fermented traditional Chinese medicine (Components: *Wolfiporia cocos* (F.A. Wolf) Ryvarden & Gilb., *Astragalus memeranaceus* (Fisch.), *Ziziphus jujuba* Mill., *Alpinia officinarum* Hance, *Angelica sinensis* (Oliv.) Diels, etc. Hebei Kexing Pharmaceutical Co., Ltd; Shijiazhuang, China);

VII Micellar traditional Chinese medicine (Components: *Astragalus memeranaceus* (Fisch.), *Codonopsis pilosula* (Franch.) Nannf., pericarpium citri reticulatae, biological enzyme, electrolyte. Goright Biotechology Co. Ltd, Chengdu, China).

A 2 × 3 orthogonal design was employed to evaluate the effects of seven functional additives on the production performance of nursery piglets. A total of 2806 piglets (Duroc × Landrace × Large White, 21 days of age, weighing 6.4 ± 0.6 kg) were grouped by sex (barrows vs gilts), bodyweight (BW) (H >6.5 kg, L <6.0 kg) and duration of feeding additives (15 d vs 30 d). They were housed in four barns, each accommodating approximately 750 piglets. Two barns were allocated for 30-d feeding additives, whereas the other two were assigned to 15-d feeding additives. In each barn, the H piglets were placed in the front and the L piglets in the rear. The barrows were housed in the left pens and the gilts were in the right pens. Both H and L piglets were divided into seven treatment groups (due to the insufficient number of L piglets, L groups fed with the V-additive (LV, other groups fed with the corresponding additive followed the same abbreviation rule) was not applicable in the 30-d group) and a control group. Each group had four pens (two pens each for barrows and gilts), and each pen had 31 piglets.

The basal diet was formulated based on NRC (2012) recommendations for nursery pig nutrition and the ideal amino acid model. The pig facilities were maintained at thermoneutral temperatures using an automatic environmental control system and mechanical ventilation system (climate controller for different sizes controlling fans). All piglets were fed with fixed quantity feeding according to age-specific intake recommendations and *ad libitum* access to water.

After a four days of adaptive feeding, the experiment commenced. The weight and survival rate of each pen were evaluated on day 0 (25 d of age), day 15 (40 d of age), day 30 (55 d of age) and day 45 (70 d of age, the end of nursery). The gained BW was calculated at these time points to evaluate the growth performance of the pig herds.

WPS Office Excel software (Jinshan Office Software Co. Ltd, Beijing, China) was used to preprocess the data, and Graphpad Prism 8.4 (Graphpad Software Inc., San Diego, USA) was used for statistical analysis. Non-paired *t*-tests were conducted to compare the BW differences between groups based on different sexes and the duration of additive supplementation, and the differences between seven additives groups and the control group were analysed using the Duncan multiple comparison test. The results were presented as mean ± standard error; P <0.05 was considered statistically significant and P <0.10 was considered a tendency.

The growth performance of the seven additive treatment groups and the control group after a feeding time of either 30 d or 15 d was presented in Table 1.There were no statistical differences in BW gain between all additive groups and the control group. It was worth noting that after feeding additives for 30 d, the HV and HVI groups had the highest gained BW (20.5 ± 0.3 kg, 20.3 ± 0.8 kg, respectively), whereas the H Control group had the lowest gained BW of 18.4 ± 0.5 kg. The gained BW of the LVI group was also higher (18.2 ± 2.3 kg) than the other groups. In terms of survival rate after a 30-d supplementation, both the HVI and HVII groups had the highest survival rates (99.2 ± 0.8%) at the end of the nursery stage, surpassing the H Control group (89.4 ± 4.0%, P <0.05). Significant differences were observed in the gained BW of the LI and L Control groups (P <0.05).

Table 1 Effects of feeding different additives for 30 or 15 days on the production performance of heavy- and light-bodyweight weaned piglets at the end of the nursery stage (± SE)

Items	Feeding (d)	Groups[1]							
		HI	HII	HIII	HIV	HV	HVI	HVII	Control
BWG (kg)	30 days	19.4 ± 0.4	19.6 ± 0.8	18.5 ± 0.5	19.6 ± 1.2	20.5 ± 0.3	20.3 ± 0.8	19.0 ± 0.9	18.5 ± 0.5
	15 days	18.1 ± 0.1	18.0 ± 0.7	18.0 ± 0.2	19.7 ± 1.0	18.7 ± 1.3	17.4 ± 0.8	17.8 ± 1.1	18.3 ± 0.5
Survival (%)	30 days	91.9 ± 1.6	92.7 ± 2.8	91.9 ± 0.9	95.2 ± 2.1	93.5 ± 1.3	99.2 ± 0.8*	99.2 ± 0.8*	89.8 ± 4.0
	15 days	90.3 ± 0.0	93.5 ± 0.0	93.5 ± 3.2	89.6 ± 9.7	90.3 ± 0.0	96.8 ± 0.0	93.9 ± 12.9	90.8 ± 2.1
		LI	LII	LIII	LIV	LV	LVI	LVII	Control
BWG (kg)	30 days	17.7 ± 0.3[a]	15.9 ± 1.2	16.7 ± 0.1	17.2 ± 0.1	Null	18.2 ± 2.3	17.0 ± 0.5	16.6 ± 0.6[a]
	15 days	13.9 ± 0.6[b]	13.8 ± 0.3	13.9 ± 0.7	15.0 ± 0.9	15.3 ± 0.8	14.3 ± 0.4	12.9 ± 1.3	12.8 ± 1.0[b]
Survival (%)	30 days	95.2 ± 1.6	95.9 ± 4.8	95.5 ± 0.0	94.5 ± 3.2	Null	93.6 ± 3.2	95.2 ± 4.8	95.4 ± 3.0
	15 days	86.9 ± 0.0	88.7 ± 1.6	91.1 ± 2.4	90.6 ± 0.8	90.3 ± 0.0	92.1 ± 3.5	91.9 ± 1.6	89.5 ± 4.7

[1]H-I, II, III, IV, V, VI, VII represent the high-bodyweight group with the seven additives, respectively.
[a,b] Different letters in the same column of the same two items differ significantly, P <0.05;* P <0.05
BWG, body weight gain

The BW of barrows and gilts in the H and L groups was similar at 25 d, 40 d, 55 d, and 70 d of age (Figure 1A). When comparing the groups that received the corresponding additives for 15 d and 30 d, the BW of the 30-d groups at 55 d and 70 d of age was higher than that of the 15-d groups (P = 0.0009 and P <0.0001, respectively) (Figure 1B).

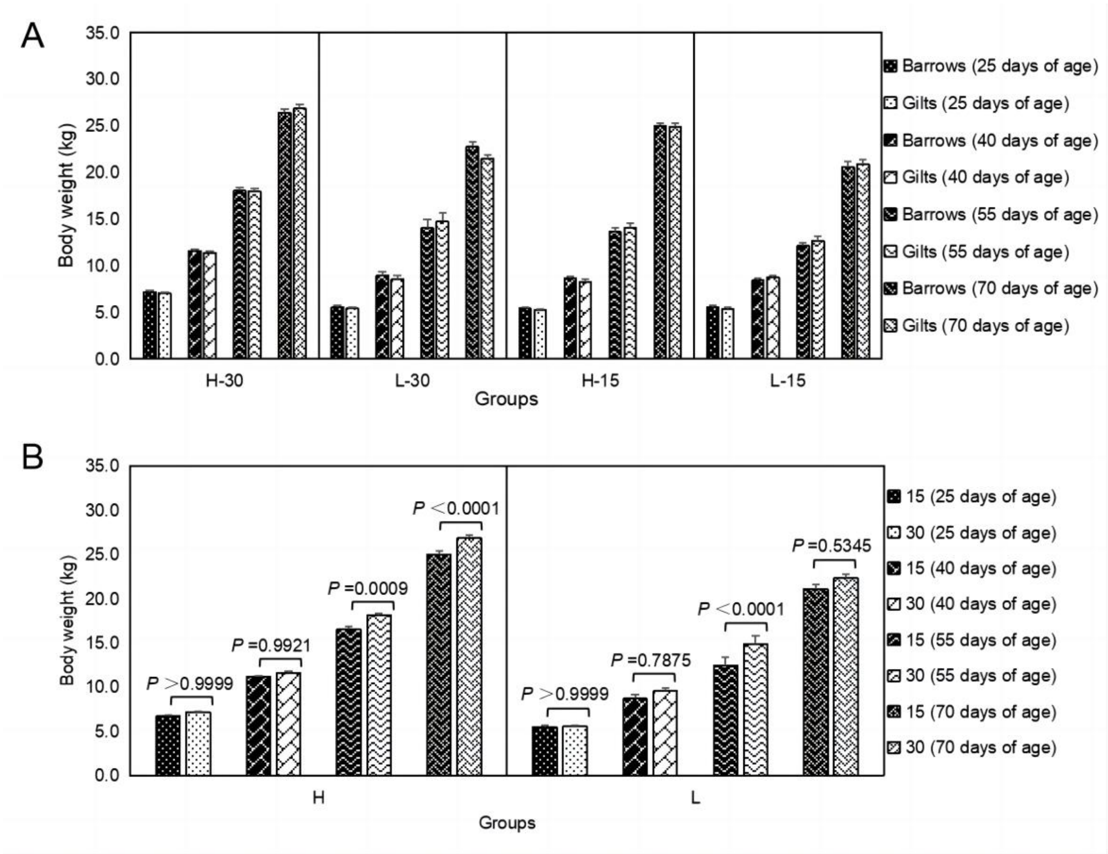

Figure 1 Comparisons of body weights (kg) at 25, 40, 55, and 70 days of age by sex (A) and duration of additive supplementation (B). At different time points, excluding the control group data, the BW of the seven additive groups were combined together. Comparative analyses (non-paired *t*-tests) were then conducted separately based on sex and the duration of additive supplementation.
H: Heavy-bodyweight. L: Light-bodyweight. H-30/H-15: Heavy-bodyweight groups with additive supplementation for 30/15 days; L-30/L-15: Light-bodyweight groups with additive supplementation for 30/15 days

Moreover, the economic benefits of the sixth group of additives was evaluated, revealing that additives improved the average end value, average cash inflow per marketing piglet and average cash inflow per kilogram of heavy BW and light BW. In comparison to the control group, the beneficial differences in heavy BW were more than double those in light BW (Table 2).

This study did not identify an optimal additive to enhance the growth performance of nursery pigs. This may be due to the large-scale field trial, where piglets were from different farrowing batches in a sow farm and then transferred to nursery-finishing pig farms. The weaned piglets were managed separately by four caretakers for each barn. Additionally, the grouping took into account the BWs of weaned piglets and sexes, as well as considering seven different types of additives and two feeding times. This may have resulted in a relatively small number of replicates for each factor (2–6 pens). Even so, we observed some trends, such as the higher survival rate in the group with Additive VI and the higher BW gain in the group with Additive V (Table 1). In practice, survival rate is one of the most intuitive and effective indicators for evaluating fattening efficiency (Guan *et al.*, 2023). As it has been found in some studies that slow-growing pigs may experience compensatory growth, the addition of certain nutrients may also enhance the growth performance of the herd (Zeng *et al.*, 2019; Camp Montoro *et al.*, 2020). Therefore, a high survival rate at the nursery stage implies the opportunity to achieve more marketing pigs.

Table 2 Production performance and evaluation of economic benefits of HVI-30

	Items	Symbol	Calculation formula	High weight groups		Low weight groups	
				Treatment	Control	Treatment	Control[1]
General	Initial age	A		26	26	26	26
	End age	B		71	71	71	71
	Days	C	= B - A	45	45	45	45
	Initial weight (kg)	D		7.28	6.53	5.58	4.61
	End weight (kg)	E		27.59	25.03	23.78	21.87
Growth performance	Gain weight (kg)	F	= E - D	20.31	18.50	18.20	17.26
	Initial number	G		124	127	62	87
	End number	H		123	114	58	87
	Survival rate	I	= H / G	99.19%	89.76%	93.55%	100.00%
	Average daily gain (kg)	J	= (E - D) / C	0.45	0.41	0.40	0.38
	Average daily feed intake (kg)	K	= N / (G + H) * 2 / C	0.60	0.60	0.53	0.53
	Feed conversion rate	L	= K / J	1.32	1.47	1.30	1.38
	Total feed consumption (kg)	N		3,315.98	3,271.58	1,422.00	2,074.95
Cost	Total feed cost ($)	O	= N * Feed price	3,159.64	3,097.46	1,345.16	1,966.88
	Feed cost per pig ($)	P	= O / (G + H) * 2	25.58	25.71	22.42	22.61
	Total additive cost ($)	Q	= N / 1000 * Additive price	144.02	——	61.76	——
	Additive cost per pig ($)	R	= Q / (G + H) * 2	1.17	——	1.03	——
	Cost of 1 kg weight gain ($)	S	= (O + Q) / F / (G + H) * 2	1.32	1.39	1.29	1.31
Economic benefits	Standard weight of piglets (kg)	T		15	15	15	15
	Marketing price of 15 kg piglets ($)	U	Market pricing	115.82	115.82	115.82	115.82
	Marketing price per kg over 15 kg ($)	V	Market pricing	3.76	3.76	3.76	3.76
	Average end value ($)	W	= U + (E - T) * V	163.21	153.57	148.86	141.67
	Average cash inflow per marketing piglet ($)	X	= W - P - R	49.70	43.93	45.06	42.36
	Average cash inflow per kg ($)	Y	= X / E	1.80	1.76	1.89	1.94
	Differences ($)	Z	= X (Treatment) - X (Control)	5.77		2.70	

[1]Only data from the pens of the L Control group housed in the same barn as the L treatment group were included in the analysis, hence slight discrepancies with the data from the Control group in Table 1
HVI-30: High body weight groups fed with the sixth additive for 30 days

This study indicated that the production performances of gilts and that of barrows in the nursery stage were similar, which was consistent with earlier research (Liu *et al*., 2016; Lee *et al*., 2018). It was obvious that the duration of additive feeding was directly proportional to the feeding cost. In order to identify a more cost-effective feeding scheme, this study compared the groups that added additives for 15 d with those for 30 d. Although the production performance of the seven additive groups showed no statistical difference to the control groups, the BW of the 30-day groups at 55 and 70 d of age was substantially higher than that of the 15-d groups (Figure 1). Cho *et al*. (2005) added 0.1% *Zizyphus vulgaris* to the basal diet for either 15 or 30 d. They found that the blood cortisol level in the 30-d group was lower, and the Hunter's L* value of loin stored for seven days increased. Guo *et al*. (2022) found that fermented traditional Chinese medicine was more effective in alleviating the diarrhoeal index and recovering the intestinal microbiota in mice than traditional Chinese medicine or probiotics (*Lactobacillus plantarum*) alone. This finding supports the results of this study regarding the positive effect of the sixth additive (fermented traditional Chinese medicine) on the survival rate and production performance. However, the mechanism of action is still unclear. Upon calculating the economic benefits, it was found that the average income per pig of HVI was higher than that of LVI, possibly due to the low daily feed and additives intake (Table 2).

Although this study did not evaluate the effects of individual functional additives, feeding different functional additives for 30 d substantially improved the BW of nursery pigs. The most cost-effective feeding procedure was to feed the H weaned piglets for 30 d.

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Authors' contributions

RG designed the experiment and wrote the initial draft this manuscript. XRQ collected and interpreted the results. JC conducted the financial analysis. KZL collaborated in interpreting the results. FJL revised initial draft of this manuscript. FTJ conducted the statistical analyses. XWL, PJ and HH finalized the manuscript. All authors have read and approved the finalized manuscript.

Conflict of interest declaration

The authors declare that there are no conflicts of interest.

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