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GROWTH PERFORMANCE AND PROFITABILITY OF WEANLING PIGS (*Sus scrofa domesticus* L.) FED PRE-STARTER DIET SUPPLEMENTED WITH NUCLEOTIDE

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ABSTRACT: Nucleotides can improve intestinal health by modulating the local immune response and intestinal mucosa development in weaned piglets. This study was conducted to evaluate the growth performance of post weaned piglets and evaluated the economic analysis of nucleotides supplementation for 30 days. A total of 120 mixed breed piglets were selected at the weaning stage and were used in the experiment as control group vs. treatment 2 supplemented with nucleotide. Each treatment consisted of 60 heads with three replications with 20 heads per replication arranged in Complete Randomized Design. Results were analyzed through Pairwise T and LSD tests. In terms of growth performance, results showed that supplementation of nucleotide had significantly increased the average daily gain, feed conversion ratio and weight gain by 0.50, 1.20 and 15.02 kg, respectively. However, there was no significant difference in terms of the average daily feed intake. With regards to the economic analysis, total production input had no effect with or without nucleotide supplementation but surprisingly, it had a gross margin of Php 95,900 (Philippine peso money) which was 5% more as with those that have supplementation. As to the net income, supplementation of nucleotides increased about 40.7% in comparison to control. Furthermore, a peso of investment could have a return of about 18 cents (1050 Php) more returns with supplementation, which apparently had 0.11 cents leverage compared to control group (0.07 cents). In conclusion, nucleotide supplementation not only improved the growth performance of post-weaned piglets but also enhanced profitability, offering a significant return on investment for swine producers. This makes nucleotide supplementation a promising strategy for improving both animal health and economic outcomes in swine production.

Keywords: Benefit Cost Ratio, Daily weight gain, Feed conversion ratio, Net Income, Nucleotides.

INTRODUCTION

Major adjustments in technologies in swine management and nutritional programs have been significantly improved for efficiency and quality in commercial swine production. Providing the primary needs of the weanling pigs, like feeds, water, and air, is crucial to their growth performances (Gaillard et al., 2020). One of the stressful moments in pig's life is on weaning, which is often accompanied by physiological variations in the gastrointestinal tract (GIT) (Pluske, 2016). Weaning is also challenging because of not only, the new atmosphere but also the transition to dry feed from sow's milk causing nutritional stress (Van Kerschave et al., 2023). One of the most health challenging experiences for pigs after weaning, is post-weaning lag (Vasa et al., 2024). Post-weaning lag is the condition where changes in the weaned pig's intestinal biochemistry can contribute to diarrhea, weight loss, a decline in appetite, and reduced growth after a new environment and the initial separation from the sow and the littermates (Dunshea et al., 2003; Muro et al., 2023). Also, after weaning, nutrient digestibility is reduced by the collapse of the intestinal barriers due to intestinal inflammation and oxidative stress (Lallès et al., 2004; Moeser et al., 2017). Thus, reducing oxidative stress by dietary nucleotides can be associated with improved health status and growth performance in nursery pigs (Jang and Kim, 2019; Duarte et al., 2019).

Dietary nucleotide supplementation to pre-starter feeds (after weaning) may provide a readily available nucleotide needed by the animals that can be used as a precursor for the maturation of intestinal mucosa, which can help alleviate the effect of early nutritional stress, brought about commonly by weaning (Correa et al., 2021). Thus, improved intestinal maturation when nucleotides are included in the diet can reduce the onset of diarrhea in weaned piglets (Martinez-Puig et al., 2007).

Nucleotides are organic molecules made up of a nitrogenous base, a pentose sugar, and a phosphate. They serve as the building blocks of nucleic acids. Nucleic acids such as deoxyribonucleic acids (DNA) and ribonucleic acids (RNA) are essential in cellular growth (Minchin and Lodge, 2019). Nucleotides can be synthesized in the body via two pathways; the first type is the de novo pathway which starts with metabolic precursors such as amino acids, ribose, carbon dioxide, and

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ammonia (Watson and Crick, 1953). The synthesis using the de novo pathway is energy-requiring. It utilizes many metabolic pathways that require a large amount of energy to proceed. In addition, some tissues in the body, like intestinal mucosa, have a limited capacity to synthesize purine nucleotides via the de novo pathway (Boza et al., 2002). Therefore, there can be a need for an exogenous supply of bases that can be utilized via salvage pathway for optimal function (Uauy et al., 1990). If the nucleotide requirements of the intestinal mucosa are quickly met, this may result in rapid intestinal development and maturation. On the other hand, the second type is the salvage pathway, which retrieves free purine and pyrimidine bases, as well as nucleosides, from the degradation of nucleic acids or from the diet (Moffatt and Ashihara, 2002; Dinardo et al., 2022). The salvage pathway is much more efficient than the de novo pathway, and this is what the study aims to develop.

The nucleosides and nucleotides are identified as bioactive compounds with significant potential for application in food and nutrition (Bezerra et al., 2024). These compounds could be integrated into functional foods to improve metabolic processes, enhance immune function, and support cellular regeneration. For infant nutrition, nucleotide fortification in infant formulas offers a strategy to replicate the immune and gut health benefits of human breast milk. Additionally, immune-boosting foods, such as soups or fortified beverages, could benefit from nucleotide inclusion to strengthen immune responses (Prakash et al., 2020). Lastly, the development of nucleotide-based dietary supplements presents an opportunity for promoting cellular health and DNA repair, highlighting the broader potential of these compounds as bioactive ingredients in food products designed for health enhancement. Moreover, previous studies found that supplementation of dietary nucleotides in nursery diets enhanced intestinal morphology (Jang and Kim, 2019; Valini et al., 2021) and intestinal immunity (Waititu et al., 2017). A research report has shown that the inclusion of a nucleotide base at a concentration of 0.5% in diets resulted in enhanced weight gain and increased feed intake among weaned pigs (Zomborszky-Kovacs et al., 2000). Moreover, it is still speculative if the efficiency of absorption of free nucleotides dissolved in water is different from that of bound nucleotides in feed ingredients (Sauer et al., 2012). Meanwhile, separate from the pig's environment, feeding strategies, age at injecting, and pig genotype and age are mediated by psychological and behavioral stress. A study has indicated that the addition of nucleotide supplementation within the range of 50 to 250 mg/kg in diets can potentially benefit newly weaned pigs. These benefits include improved growth performance, potentially attributed to reduced intestinal inflammation and oxidative stress, as well as enhanced intestinal villi structure and energy digestibility (Jang and Kim, 2019). However, little is known about the information on the effects of nucleotide on the growth of newly weaned piglets. Thus, present study was conducted to evaluate the effects of nucleotide supplementation on the nutrient digestibility and growth performance of pigs when added to pre-starter feedings over a period of 30 days.

MATERIALS AND METHODS

Time and place of study

The experiment was conducted at the Nursery Section, Department of the Research and Development Farm of UBC Stock Farm, Incorporated at Sitio Dao, Brgy. Singsing, Balamban, Cebu, Philippines from October to November 2023.

Experimental design and layout

The 120 heads total of mixed-breed newly weaned pig (Landrace × Duroc × Large White) were chosen at the weaning stage. A Completely Randomized Design (CRD) was used in the experiments with two experimental treatments, the control group (T1) consisted of weaned pigs given pure pre starter diet (without nucleotide supplementation) and treatment T2 were pigs supplemented with nucleotides added in the formulated feeds. Each group contained 60 heads which was further divided into 3 subgroups representing the three replications. The selection of the newly weaned piglets was based on their size and uniformity, as well as their sex, to ensure a fair distribution of males and females in each treatment group.

Care and management

Before conducting the experiment, the pen underwent thorough cleaning, disinfection, and sanitation process for approximately 14 days. This was done prior to transferring the pigs from the farrowing section to the weaning area. Each pen was provided with rotary feeders and one linear feeder. Feeds and clean water were provided in an ad libitum scheme. Vitamins and mineral supplements were administered via drinking water upon loading via medicator tank and during stressful periods such as challenging weather (extreme cold and extreme heat) and disturbance stress. Curtains and lighting were also installed on a case-by-case basis to provide the most comfortable conditions for the newly weaned pigs. Vaccination of Hog Cholera at 35 days old and *Mycoplasma pneumonia* and *Haemophilus parasuis* 2 at 42 days old was administered to all the experimental pigs.

Experimental diets

Both groups were administered the same feed formulations of the pre-starter diet. Group 2 animals received the pre-starter diet with 500 grams of nucleotide per ton of feeds. The nucleotides were included during the mixing of feeds in the feed mill where the feeds were produced. The source of nucleotide was provided from the yeasts extracts through hydrolysis (Bioiberica, Spain, Table 1).

Table 1 - Nucleotide concentration (ppm) in some commonly used feed ingredients (as-is basis) (Mateo et al., 2004)

Ingredient	Nucleotide: 5' -AMP	5'- CMP	5'-GMP	5'-IMP	5'-UMP
Barley	1	2	1	1	0
Casein	0	1	0	0	0
Corn	2	3	3	1	0
Fishmeal	11	26	2	35	1
Naked oats	3	3	3	1	1
Non-fat dried milk	0	65	0	195	106
Plasma protein, spray dried	2	2	2	1	0
Red blood cells, spray dried	44	0	3	6	2
Soybean meal, 44%	8	16	3	2	9
Soy protein concentrate	1	0	2	1	0
Whey dried	19	270	0	4	1
Whey protein concentrate	0	34	0	159	89

Adenosine 5' monophosphate (5' AMP), cytidine 5' monophosphate (5' CMP), guanosine 5' monophosphate (5' GMP), inosine 5' monophosphate (5' IMP), and uridine 5' monophosphate (5' UMP)

Data Collection

Body weight and feed measurements

From the first day to the day 30 of feeding, both feed consumption and body weights of the experimental animals were monitored. The collected data was analyzed, summarized, and categorized according to metrics like the ADG or Average Daily Gain, the ADFI or Average Daily Feed Intake, and the FCR or Feed Conversion Ratio (FCR) during the entire feeding duration. Additionally, calculations were made: 1) feed price per pig; 2) feed price per kilo of gain; 3) income over feed and 4) pig price.

Body weight and weight gain

The body weight at weaning (start of feedings) and after 30 days of feedings (end of feedings) was determined and recorded. The average body weight for each replicate was determined by dividing the group weight by the number of pigs in each pen. To determine the body weight gain for each replicate, the final weight at the end of the experiment was subtracted from the initial body weight.

Feed consumption

The feed intake of the pigs was be calculated by subtracting the number of left-over feeds from the amount of feed offered divided by the corrected number of pigs (less mortality).

Feed conversion ratio

The feed conversion ratio was determined by dividing the feed consumption by the corresponding weight gain at the conclusion of the pre-starter feeding period for each replicate.

Economic analysis

Variable cost of the treatments

Cost of Treatment 1 = total cost of compounded feeds given + other cost, if any

Cost of Treatment 2 = total cost of compound feeds + nucleotide supplements, other cost, if any.

To calculate the financial return, the total expenses were subtracted from the total expected sales.

Net profit = Total sales – Total Expenses

Where:

Total sales = were calculated by multiplying the final weights of the pigs by the current selling price.

Total expenses = were expenses incurred throughout the experiments.

Benefit-cost ratio

The discounted cash inflows and outflows ratios, which must be equal to or larger than one, are known as the Benefit-cost ratio (BCR). The ratio must be at least 1:1, indicating that the expense incurred and the benefit received are equal. If the benefits outweigh the costs, the ratio should be greater than 1. This parameter shows the rate of return and is worked out by dividing the total gross return by the total cost return.

$$BCR = \frac{\text{Total Gross Return}}{\text{Total Cost}}$$

Statistical analysis

The data were analyzed using STAR version 2.0.1 or Agricultural Statistics software. Pairwise t-test analysis was used to compare treatments, while Least Significant Difference (LSD) test was used to determine significant differences between responses variables among different treatments in the study to ensure the reliability of the results obtained.

RESULTS AND DISCUSSION

Growth performance of pigs

The effectivity of nucleotide supplementation on post-weaned pigs has been studied earlier, showing contradicting results including but not limited to its dietary effects (Perricone et al., 2020), physiological attributes (Reina et al., 2014), and immune system (Superchi et al., 2012). Nonetheless, the effectiveness of nucleotide supplementation on post-weaned piglets has been the focus of the study.

Different growth performance or test variables have been tested in the study, including the average daily gain (ADG), feed conversion ratio (FCR), and weight gain (WG). As presented in Table 2, the effect of supplementation of nucleotide to the pre-starter on post-weaned had significantly improved their ADG, FCR, and WG, respectively. Results showed that nucleotide supplementation had significantly increased the daily gain by approximately 0.07 kg compared to the treatment without nucleotide supplementation. Regarding this, the results may be attributed to the positive effects of nucleotide supplementation to enhance nutrient absorbability in the small intestine by promoting the development of enhanced villi. This, in turn, leads to improved performance in pigs. The findings of this study are consistent with previous literature that has reported varying outcomes concerning nucleotide supplementation in pigs. For instance, Perricone et al. (2020) found that nucleotide supplementation can positively affect dietary intake and growth metrics, albeit with differing results based on the specific composition and dosage of nucleotides used. Similarly, Reina et al. (2014) reported improvements in physiological attributes associated with nucleotide intake, while Superchi et al. (2012) highlighted enhancements in immune response. While some studies have reported contradictory outcomes regarding the effectiveness of nucleotides on growth performance, this research supports the notion that, when utilized correctly, nucleotides can significantly enhance growth metrics. The discrepancies observed in previous studies may be attributed to various factors, including differences in experimental design, genetic backgrounds of the pigs, and environmental conditions, which can all influence nutrient metabolism and growth performance (Rocadembosch et al., 2016; Pierozan et al., 2016).

Table 2 - Growth performance of pigs during the pre-starter stage in the post-weaning period (PWP), comparing those feds with and without nucleotide supplementation.

Treatment	Average daily gain (kg)	Feed conversion ratio	Average daily feed intake (kg)	Weight gain (kg)
T1 (Without Nucleotide)	0.430 [b]	1.47 [a]	0.64	13.04 [b]
T2 (With Nucleotide)	0.500 [a]	1.20 [b]	0.63	15.02 [a]
P-Value	0.03	0.04	0.56	0.03
F Value	9.50	8.74	0.40	9.52
CV %	5.41	8.49	2.04	5.60

Means with the same letter designations were not significantly different at 5% level LSD test.

Feed conversion ratio served as the feed used per pound of weight gain. The results of the study demonstrated that the supplementation of nucleotides effectively reduced the amount of feed required to produce a kilogram of live weight. It takes only 1.20 kg of feeds to have a kilogram of its equivalent live weights. A lower FCR indicates that pigs are efficiently converting feed into body weight. The Feed Conversion Ratio (FCR) in pigs can differ across countries (Rocadembosch et al., 2016), stages of growth (Pierozan et al., 2016), environmental conditions (Agostini et al., 2014), and genetic factors (Bereskin, 1986). However, as a general guideline, a pig's FCR should ideally fall within the range of 3:1. In terms of the weight gain, results showed that the higher the average daily gain, this also resulted to a higher weight gain at harvesting (Table 2). Statistical evidence demonstrated that nucleotide supplementation resulted in a significant increase in live weight by 15.02 kg, which corresponds to a 7% higher weight compared to the group without nucleotide supplementation.

Statistical analysis showed no significant difference between the two treatments, indicating no effects on the daily feed intake. Based on the findings, the addition of nucleotide supplementation increased the average daily gain, feed conversion, and ultimately the live weight gain of post-weaned pigs. This indicates that nucleotide supplementation positively impacted the growth and performance of the pigs. Other scientists have also confirmed the effectiveness of nucleotides, not only in terms of improving growth performance but also in boosting the immune system and reducing environmental stresses. This indicated that nucleotides have multiple beneficial effects beyond just promoting growth in animals. Nucleotides have important effects on the growth and development of rapid turnover cells, such as those in the immune system and the gastrointestinal (GI) tract (Dancey et al., 2006) However, it has been observed that animals fed diets lacking in nucleotides exhibit lower immune responses, as noted by Chandra and Kumari (1994). This suggests that the absence of nucleotides in the diet can negatively impact the immune system of animals. Dietary nucleotides recognized a potential antibiotic alternative, have been found to exhibit beneficial effects on intestinal hyperemia, systemic immunity, small-intestinal growth, and hepatic composition in pigs (Jang and Kim, 2019). Moreover, Sauer et al. (2011) summarized that supplementation of nucleotides affects immune function, nutrient metabolism, hepatic morphology and function and accelerates T-cell-dependent antibody production (Grimble et al., 2001)

Economic analysis of piglets

Economic analysis of pigs differs due to several reasons like breed type, cost of feeds fed, operating expenses, vitamins and medicine for diseases of pigs, market niche, current buying price, location, and demand pool in the society. In this study, the computation of the total variable cost is based on the existing care and maintenance practices that are uniformly applied to all blocks (Table 3). This means that the cost calculations consider the standard care and maintenance procedures that are consistently implemented across all blocks. The variable cost includes the price of pigs (20 heads per block), feeds, electricity, water, managerial pay/labor cost, as well as vaccines and vitamins. According to the analysis, there is no significant difference observed in terms of variable cost. This means that the addition of nucleotides does not result in any significant variation in the production inputs required for raising pigs. In terms of its gross income, calculation includes the total live weight of 20 pigs at harvest times at a price of each pig at 210 per kilogram, which was applied and computed to all blocks.

Table 3 - Economic analysis of swine production at the pre-starter stage during the post-weaning period (PWP), comparing the outcomes with and without the inclusion of nucleotides.

Treatment	Total per Philippine Peso		Net income	Benefit cost ratio
	Variable cost	Gross income		
T1 (Without nucleotide)	81,497.67	87,535 [b]	6,037.33 [b]	1.07 [b]
T2 (With nucleotide)	81,574.33	95,900 [a]	14,325.49 [a]	1.18 [a]
P Value	0.82	0.05	0.04	0.04
F Value	0.06	7.67	9.20	8.98
CV %	0.49	4.03	32.86	3.75

Means with the same letter designations were not significantly different at 5% level LSD test.

The study results indicate that nucleotide supplementation leads to higher live weight, resulting in a higher gross income during harvesting. The statistical results indicated that nucleotide supplementation has significantly increased income compared to the non-supplemented group. A gross income of Php 95,900 (1648.39 USD) was incurred with nucleotide supplementation, which is 3 percent (3.84%) higher compared to Php 87,535 (1504.61 USD) without nucleotide supplementation. It simply means that the higher the gross income compared to variable cost, the higher is the net income. It is true that this study has significant implications, as the supplementation of nucleotides in T2 resulted in a 40.70 percent leverage compared to T1 (without nucleotide supplementation). Moreover, in terms of its benefit-cost ratio, the use of nucleotide supplementation incurred 1050 Php (18 cents) return on a peso of investment. This demonstrated a significant difference, with a lower return on the treatment without supplementation, yielding only 0.07 cents of return on each peso of investment.

Generally, the study implies that the addition of nucleotide supplements does not affect the overall production cost. However, it positively impacts the gross income by increasing pig live weights, net income, and the return on peso investment by 18 cents per peso, respectively.

CONCLUSION

The addition of nucleotide supplementation resulted in developments in average daily gain, feed conversion ratio, and the weight gain, although it did not have a significant impact on the average daily feed intake. Also, in terms of its economic analysis, supplementation of nucleotide had shown no effect on the total production cost but had higher gross income with 5% leverage as compared to control group, 40.70% increase in net income, and a higher benefit of 18 cents for a peso spending compared to treatment without supplementation.

DECLARATIONS

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Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Ethical considerations

This study adhered to the Animal Welfare Act of the Philippines 1998 (The Philippine Animal Welfare Society, 1998) to ensure the humane treatment of the post-weaned piglets. Proper care, including adequate housing, nutrition, and veterinary support, was provided throughout the experiment. Stress and pain were minimized by handling the piglets gently and using trained personnel for all procedures. Clear criteria for humane endpoints were established. The number of animals used was kept to the minimum necessary to achieve valid results, following the principle of reduction. The study-design ensured that the use of animals was ethically justified by the potential benefits to swine production (FAO, 2015).

Authors' contribution

Both authors contribute on conceptualization of the study, data analysis and the write up of the manuscript

Competing interests

The authors declare no competing interests in this research and publication.

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