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Effect of Natural Bioactive Compounds versus Ractopamine: A) On Productivity

Guadalupe Edgar Beltrán-Rosas[1], Néstor Méndez-Palacios[2*], José Alfredo Galicia-Domínguez[2], Maximino Méndez-Mendoza[2]

[1]Technical Director in Swine, Phytogenic Feed Additive, Ebios Nutrition S.A.P.I. de C.V., Monterrey, México
[2]Facultad de Medicina Veterinaria y Zootecnia, Benemérita Universidad Autónoma de Puebla, Puebla, México
Email: *nestor.mendezp@correo.buap.mx

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Abstract

Background: The removal of ractopamine from swine production, demanded by both export and local markets, represents a challenge for the swine industry. This study evaluated the effect of AO NATURAL FIT PRO® as an alternative to ractopamine on productive performance. **Methods:** Thirty-two castrated male pigs (62 ± 2.5 kg initial weight) were randomly assigned to four treatments: control, AO NATURAL FIT PRO® for 8 weeks, ractopamine 10 ppm for 5 weeks, and a combination of both additives. Productive performance parameters were evaluated. **Results:** The supplemented groups showed significant improvements ($P < 0.05$) in final live weight (106.357, 106.500, and 105.710 kg for T2, T3, and T4, respectively, compared to 97.416 kg for the control group), average daily gain, and feed efficiency. Hot carcass weight was higher in the treated groups (77.817, 78.767, and 79.071 kg) compared to the control group (71.333 kg). The combined treatment showed the least weight loss during transport (1.81%). **Conclusions:** AO NATURAL FIT PRO®, ractopamine, and their combination improved productive performance. The natural additive represents a viable alternative to ractopamine for optimizing swine production efficiency.

Keywords

Swine, Productivity, Natural Bioactive Compounds, Ractopamine, Meat Quality

1. Introduction

The acceleration of modern lifestyles, associated with urbanization and globalization, has led to a sustained increase in the demand for natural resources, waste generation, and the emission of pollutants. This phenomenon, driven by popula-

tion growth and per capita consumption, has been exacerbated by economic development and rising incomes, which have increased the demand for food products [1]. In this context, pork production is geared towards supplying meat consumption, both locally and for export. However, the use of inputs and raw materials significantly influences the final price of the product [2].

To optimize the profitability of pig farms, the use of feed additives and supplements, such as antibiotics, hormones, and β-agonists, is common [3]. These allow for the implementation of precision feeding programs that help animals express their maximum genetic potential at different physiological stages, thus improving traceability and farm sustainability [2]. In the livestock industry, certain additives are used to improve feed efficiency, increase growth performance, and decrease carcass fat content without altering quality [4] [5].

Among these additives, ractopamine hydrochloride (RAC) stands out. It is a phenylethanolamine with a structure similar to that of natural β-agonists (epinephrine and norepinephrine) and synthetic ones such as clenbuterol [6]-[8]. Pharmacologically, RAC stimulates β1 and β2 adrenergic receptors in skeletal muscle and adipose cells, activating signaling pathways that promote lipolysis and, consequently, increase lean carcass tissue [9]-[11]. Despite its approval in countries such as the United States, Canada, Mexico and Brazil, the use of RAC is prohibited in the European Union, China and other nations [12] [13].

The use of β-agonists has been questioned due to their adverse effects. Animals treated with RAC have been reported to be more susceptible to injury and anxiety during transport, an unavoidable process in intensive farming that itself induces stress and negative physiological changes, such as weight loss, fractures, and reduced muscle glycogen. The latter affects the proper transformation of muscle into meat, causing quality problems (dark cuts or pale, soft, and exudative meat) and economic losses [14]-[16]. Furthermore, the use of these additives has been associated with increased mortality rates and leg injuries in cattle [8] [17]. The presence of residues of these compounds in meat for consumption poses a potential risk to human health, which underlines the need to investigate the mechanisms of protection of the human body against these additives and to obtain scientific evidence on their toxicity [5] [8].

Alternatively, the use of phytogenic additives, bioactive compounds derived from plant extracts rich in antioxidants such as phenols, flavonoids, vitamins, and minerals, has become widespread in the last decade [18]-[20]. These compounds promote the elimination of free radicals and protect the organism from oxidative stress, improving the overall health of animals [18] [21]. The combination of these compounds with methyl group donors and organic acids, along with good management practices, is presented as a key strategy for maximizing productive performance sustainably [18] [22].

The withdrawal of ractopamine, mandated by both export and domestic markets, along with the negative effects of stress, presents a challenge for the swine industry in Mexico. This creates a need to find effective substitutes that do not

compromise human health and allow access to international markets without restrictions. Consequently, this study was designed to evaluate the effect of the AO NATURAL FIT PRO® supplement as an alternative to ractopamine on the productive performance—Daily Gain, Feed Intake, and Feed Conversion Ratio—of pigs during the growing-finishing stage.

2. Materials and Methods

2.1. Location and Experimental Conditions

The study was conducted at a commercial farm, in a building designated exclusively for the experiment. This allowed the animals to be kept free from external disturbances and under controlled and standardized environmental and management conditions.

2.2. Animals, Housing, and Management

Thirty-two castrated male pigs from a commercial line, in the growing-finishing stage, with an average initial live weight of 62 ± 2.5 kg, were used. The animals were randomly assigned to four treatments, with eight replicates per treatment. Each pig was housed in an individual 1.2 m^2 pen, equipped with a hopper feeder and nipple drinker, and was considered the experimental unit. Feed and water were offered *ad libitum* throughout the experimental period. To maximize voluntary intake, 10% more feed was provided than the amount consumed the previous day.

2.3. Experimental Diets and Treatments

The basal diets (Table 1) were formulated to meet or exceed the nutritional requirements for pigs in the growing and finishing phases. All treatments were supplemented with the following enzymes: phytase (10 g/100 kg), xylanase (15 g/100 kg), protease (40 g/100 kg), and a mycotoxin adsorbent (Micofix, 150 g/100 kg). The treatments were:

- **Control:** Basal diet without additives (without ractopamine and without the AO Natural Fit Pro supplements).
- **AO NATURAL FIT PRO®:** Baseline diet supplemented with the additive for the 8 weeks prior to slaughter. AO NATURAL FIT PRO® is a bioactive compound derived from plants containing extracts of purple basil, oroval, Indian gooseberry, and garlic, which act as antioxidants and help protect animals from oxidative stress. Other derivatives include tannins, found in fruits and seeds; these are polyphenols with antioxidant and anti-inflammatory properties used in nutrition for their health benefits.
- **Ractopamine:** Basal diet supplemented with 10 ppm of ractopamine for the 5 weeks prior to slaughter.
- **AO NATURAL FIT PRO® + Ractopamine:** Basal diet supplemented with both additives, administered according to the timings of treatments 2 and 3, respectively.

2.4. Response Variables and Laboratory Analysis

The study was conducted as follows: Evaluation of Productive Response in the Field.

The productive performance trial lasted 56 days (8 weeks). Feed intake and individual live weight (LW) were recorded weekly to calculate average daily gain (ADG), average daily feed intake (ADF), and feed conversion ratio (FCR), calculated as: FCR = Feed intake (g)/Live weight gain (g).

At the end of the experimental period, the 32 pigs were transported to the municipal slaughterhouse in Toluca, State of Mexico, where they were slaughtered using humane methods approved by current regulations. The hot carcass weight (HCW) was obtained, and the relative weights of the carcass and its components were calculated in relation to the final live weight (g/kg LW).

For the chemical analysis of the diets, 250 g samples of feed were collected weekly from each phase (growth and finishing). At the end of the study, the samples from each phase were mixed to form a composite sample, which was ground (1 mm sieve) and analyzed in duplicate to determine the content of dry matter, ash, crude protein, and ether extract, according to the AOAC methods [23]. **Table 1** shows the ingredient and nutritional composition for pigs from 50 to 100 kg live weight.

Table 1. Composition of ingredients of the basal diet and nutrient composition for pigs from 50 to 100 kg of live weight.

Ingredients (kg)	Treatment				Nutritional requirements (NRC 2012)
	Control	AO NATURAL FIT PRO®	Ractopamine	AO NATURAL FIT PRO® + Ractopamine	
Corn	55.11	54.96	55.06	54.96	
Sorghum	9.2	9.2	9.2	9.2	
Soybean meal	26.51	26.51	26.51	26.51	
Wheat bran	5	5	5	5	
Vegetable oil	1	1	1	1	
Vitamin premix	0.05	0.05	0.05	0.05	
Mineral premix	0.1	0.1	0.1	0.1	
Calcium carbonate	1.3	1.3	1.3	1.3	
Orthophosphate	0.8	0.8	0.8	0.8	
Lysine	0.4	0.4	0.4	0.4	
Threonine	0.3	0.3	0.3	0.3	
Methionine	0.2	0.2	0.2	0.2	
AO NATURAL FIT PRO®	-	0.15	-	0.1	
Ractopamine	-	-	0.05	0.05	

Continued

Additives1	0.0215	0.0215	0.0215	0.0215	
Total	100	100	100	100	
		Calculated nutritional value			
Dry matter (%)	89.1	89.1	89.1	89.1	
Net energy (Mcal/Kg)	2.50	2.50	2.50	2.50	2.47
Crude protein (%)	16	16	16	16	
Ether extract (%)	3.29	3.29	3.29	3.29	
Crude fiber (%)	3.64	3.64	3.64	3.64	
Calcium (%)	0.76	0.76	0.76	0.76	0.75
Phosphorus (%)	0.63	0.63	0.63	0.63	0.62
Lysine (%)	1.20	1.20	1.20	1.20	1.16
Threonine (%)	0.80	0.80	0.80	0.80	0.74
Methionine (%)	0.38	0.38	0.38	0.38	0.34

[1]Included in all groups = Phytase 10 g/100 kg, Xylanase 15 g/100 kg, Protease 40 g/100 kg, Micofix 150 g/100 kg.

2.5. Statistical Analysis

The data were analyzed using an analysis of variance (ANOVA) for a completely randomized design, using the GLM procedure of the SAS software [24]. The statistical model used was:

$$y_{ij} = \mu + \tau_i + \varepsilon_{ij},$$

where y_{ij} is the observation value,

μ is the population mean,

τ_i is the treatment effect, and

ε_{ij} is the experimental error.

The experimental error was assumed to follow a normal distribution. Differences between treatment means were considered significant at a $p < 0.05$ level and were compared using Tukey's test.

3. Results

The pigs used in this study remained clinically healthy throughout the experimental phase.

3.1. Productive Performance

Table 2 shows the productive behavior of pigs in the growth-finishing stage, where it was observed that the weights of the pigs were statistically similar for the four treatments, however, the animals to which AO NATURAL FIT PRO®, Ractopamine

and AO NATURAL FIT PRO® + Ractopamine were added had higher values ($P < 0.05$) in final live weight (kg) (106.357, 106.500 and 105.710, respectively) while the control group reached a live weight of (97.416 kg), total weight gain (kg) (44.169, 44.000 and 43.210, respectively), while the control group had (35.228), daily weight gain (gr) (788.73, 785.71 and 771.60, respectively) for the control group was (629.07); Feed efficiency (0.295, 0.309, and 0.298, respectively) was higher in the control group than in the AO NATURAL FIT PRO® diet (0.252). However, feed conversion ratio was higher in the control group (3.95) compared to the diets supplemented with AO NATURAL FIT PRO®, Ractopamine, and AO NATURAL FIT PRO® with Ractopamine. Regarding total feed intake and daily feed intake, the results were statistically similar for all four treatments.

Table 2. Productive performance of treated pigs in the growth-finishing stage.

Parameter	Treatment				SEM[1]	P-value
	Control	AO NATURAL FIT PRO®	Ractopamine	AO NATURAL FIT PRO® + Ractopamine		
Initial live weight (kg)	62.188	62.188	62.500	62.500	1.370	0.996
Final live weight (kg)	97.416[b]	106.357[a]	106.500[a]	105.710[a]	2.480	0.042
Total weight gain (kg)	35.228[b]	44.169[a]	44.000[a]	43.210[a]	1.650	0.013
Daily weight gain (g)	629.07[b]	788.73[a]	785.71[a]	771.60[a]	0.029	0.011
Total feed intake (kg)	139.28	149.58	142.38	144.91	6.130	0.654
Daily feed intake (kg)	2.487	2.671	2.542	2.587	0.097	0.607
Feed conversion ratio	3.95[a]	3.38[b]	3.23[b]	3.35[b]	0.100	0.004
Feed efficiency	0.252[b]	0.295[a]	0.309[a]	0.298[a]	0.008	0.006

[1]Standard error of the mean. [a]Greater difference, [b]Lesser difference.

3.2. Effects during Transport and Pre-Slaughter

During weight loss in pigs during transport and the pre-slaughter rest period, pigs receiving the supplement AO NATURAL FIT PRO®, ractopamine, and AO NATURAL FIT PRO® + ractopamine had the highest weights ($P < 0.05$) for live weight after transport (103.771) and live weight at slaughter (101.500) compared to the control group, while the weights with the AO NATURAL FIT PRO® and ractopamine groups were similar. Furthermore, the AO NATURAL FIT PRO® + ractopamine group lost only 1.81% of their weight during transport compared to the other groups. There were no differences in the percentage of total weight loss (transport and pre-slaughter rest) between treatments. Detailed information can be found in Table 3.

Table 3. Weight loss of pigs during transport and pre-slaughter rest period.

Parameter	Treatment				SEM[1]	P-value
	Control	AO NATURAL FIT PRO®	Ractopamine	AO NATURAL FIT PRO® + Ractopamine		
Live weight after transport (kg)	94.330[b]	102.214[a]	102.200[a]	103.771[a]	2.28	0.029
Live weight at slaughter (kg)	92.833[b]	100.500[a]	101.250[a]	101.500[a]	2.47	0.050
% Loss during transport	3.13[b]	3.84[ab]	4.04[a]	1.81[b]	0.574	0.033
% Total loss (transport + rest)	4.67	5.53	4.94	3.99	0.440	0.091

[1]Standard error of the mean. [a]Greater difference, [b]Lesser difference.

4. Discussion

4.1. Productive Performance

Oxidative stress in pigs is an imbalance between free radicals and antioxidants, making it crucial during weaning and transport. It causes cellular damage, reduces productive performance (lower weight gain, more fat, less muscle), and impairs intestinal health [18] [21]. It can be addressed with nutritional strategies, including antioxidants such as natural antioxidants and polyphenols. However, it is important to mention that there are triggering factors, such as weaning stress, intensive production, and environmental factors (extreme temperatures, mycotoxins in feed, and transport) [15] [25]. This impacts swine production, causing structural damage to the intestine and resulting in reduced nutrient absorption. The same occurs with meat quality, as pigs accumulate more fat and less protein. Control strategies include supplementation with functional antioxidants, improved management to avoid stress, providing high-quality feed that avoids oxidized ingredients, and minimizing mycotoxin load [22]. Based on these strategies, pigs supplemented with AO NATURAL FIT PRO®, ractopamine, and their combination showed significant improvements ($P < 0.05$) in final live weight (106.357, 106.500, and 105.710 kg, respectively), average daily gain, and feed efficiency compared to the control group. These results are consistent with those reported by Andretta *et al*. [26] and Ferreira *et al*. [27], who documented improvements of up to 10% in average daily gain and 12% in feed efficiency with ractopamine administration.

The improvement in feed conversion indicates more efficient feed utilization, suggesting a complex interaction between additives and growth performance [28]. Notably, no significant differences in total feed intake were observed between treatments, indicating that the observed effects are due to improved metabolic utilization of nutrients [29], rather than increases in voluntary intake.

As Herrera *et al*. [30] point out, although natural additives such as AO NATURAL FIT PRO® can improve palatability, feed acceptance does not necessarily guarantee better feed efficiency. Our results corroborate this observation, as the improvements in efficiency occurred without significant changes in feed in-

take and, therefore, in feed conversion.

The absence of evident synergistic effects between AO NATURAL FIT PRO® and ractopamine suggests independent mechanisms of action. Both additives, used individually or in combination, represent viable strategies to improve pig production performance without requiring increases in feed consumption.

4.2. Effects during Transport and Pre-Slaughter

During the critical transport and pre-slaughter rest period, pigs supplemented with AO NATURAL FIT PRO®, ractopamine, and their combination maintained higher weights ($P < 0.05$) both after transport (103.771 kg) and at slaughter (101.500 kg) compared to the control group. The group receiving the AO NATURAL FIT PRO® + ractopamine combination showed the least weight loss (1.81%), suggesting a protective effect against transport stress.

These findings are consistent with Brown *et al*. [31] and Warriss *et al*. [32], who documented that certain supplements can significantly reduce transport-related stress. The significant weight retention in the supplemented groups highlights the importance of pre-slaughter nutrition, as noted by Brizgys *et al*. [33], and suggests that both additives may be effective in maintaining body weight under stressful conditions [34].

It is important to recognize that, although the results demonstrate clear benefits of supplementation, prolonged transport can induce physiological stress responses that are not fully mitigated by nutritional interventions alone [31]. Therefore, a comprehensive approach that combines nutritional strategies with optimized management practices is essential to maximize both animal welfare and productivity [35].

The absence of evident synergistic effects between AO NATURAL FIT PRO® and ractopamine during the production phase contrasts with the possible combined effect observed during transport, suggesting complementary mechanisms of action under stressful conditions. Both additives represent viable strategies for improving production performance and reducing losses associated with pre-slaughter handling.

5. Conclusions

The results demonstrate that supplementation with AO NATURAL FIT PRO®, ractopamine, and their combination generates differentiated effects on productive parameters in pigs during the growing-finishing stage. Supplementation significantly improved ($P < 0.05$) final live weight, total weight gain, average daily gain, and feed efficiency, without increasing feed intake. These effects are mainly due to improved metabolic utilization of nutrients, establishing these additives as viable strategies for optimizing productive efficiency. During transport and pre-slaughter rest, the supplemented groups maintained higher weights, with the AO NATURAL FIT PRO® + ractopamine combination showing the least weight loss during transport (1.81%), suggesting a protective effect against transport stress.

The findings reveal a dichotomy between the evident productive benefits and the limited or adverse effects on certain sensory quality attributes. The absence of consistent synergistic effects between AO NATURAL FIT PRO® and ractopamine suggests complementary mechanisms of action that manifest themselves differentially depending on specific physiological conditions.

The implementation of these additives in commercial swine production systems must carefully consider the balance between improvements in production efficiency and carcass yield versus potential compromises in specific sensory attributes. This comprehensive evaluation is essential to optimize both the profitability of the production system and the acceptability of the final product.

Conflicts of Interest

None of the authors have a conflict of interest.

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