Effects of Yeast Cell Wall Polysaccharides on Peripheral Blood Immunity and Intestinal Immunity in Weaned Piglets: Postprint

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Abstract

This experiment aimed to investigate the effects of dietary supplementation with yeast cell wall polysaccharides on peripheral blood immunity and intestinal immunity in weaned piglets. A single-factor experimental design was adopted, and 180 weaned piglets at 21 days of age with similar genetic background, parity, and body weight were selected and randomly divided into 4 groups, with 5 replicates per group and 9 piglets per replicate. The four groups were fed experimental diets supplemented with 0 (control group), 0.15%, 0.30%, and 0.45% yeast cell wall polysaccharides, respectively. The experimental period lasted 21 d. The results showed: 1) Compared with the control group, dietary supplementation with 0.15%, 0.30%, and 0.45% yeast cell wall polysaccharides significantly increased serum immunoglobulin A (IgA) content in weaned piglets ($P<0.05$), and dietary supplementation with 0.30% and 0.45% yeast cell wall polysaccharides significantly increased serum immunoglobulin G (IgG) content in weaned piglets ($P<0.05$). 2) Compared with the control group, dietary supplementation with 0.15%, 0.30%, and 0.45% yeast cell wall polysaccharides significantly decreased serum interferon-γ (IFN-γ) content in weaned piglets ($P<0.05$), and dietary supplementation with 0.30% yeast cell wall polysaccharides significantly increased serum interleukin-10 (IL-10) content in weaned piglets ($P<0.05$). Dietary supplementation with yeast cell wall polysaccharides had no significant effects on serum interleukin-2 (IL-2), interleukin-6 (IL-6), and tumor necrosis factor-α (TNF-α) contents in weaned piglets ($P>0.05$). 3) Compared with the control group, dietary supplementation with 0.30% and 0.45% yeast cell wall polysaccharides significantly increased ileal CD4+ lymphocyte content in weaned piglets ($P<0.05$), and dietary supplementation with yeast cell wall polysaccharides could increase ileal CD8+ and CD20+ lymphocyte contents in weaned piglets to a certain extent, but the differences were not significant ($P>0.05$). It can be concluded that yeast cell wall polysaccharides can improve peripheral blood

immunity and intestinal immunity in weaned piglets to a certain extent and alleviate weaning stress.

Full Text

Effects of Yeast Cell Wall Polysaccharide on Peripheral Blood and Gut Immunity of Weaned Piglets

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Abstract

This experiment was conducted to investigate the effects of dietary yeast cell wall polysaccharide on peripheral blood and gut immunity in weaned piglets. Using a single-factor experimental design, 180 piglets weaned at 21 days of age with similar genetic background, parity, and body weight were randomly allocated to 4 groups, each consisting of 5 replicates of 9 piglets. The four groups were fed experimental diets supplemented with 0 (control), 0.15%, 0.30%, and 0.45% yeast cell wall polysaccharide, respectively. The experimental period lasted 21 days. The results showed: (1) Compared with the control group, dietary supplementation with 0.15%, 0.30%, and 0.45% yeast cell wall polysaccharide significantly increased serum immunoglobulin A (IgA) content ($P<0.05$), while 0.30% and 0.45% supplementation significantly increased serum immunoglobulin G (IgG) content ($P<0.05$). (2) Dietary supplementation with 0.15%, 0.30%, and 0.45% yeast cell wall polysaccharide significantly decreased serum interferon-γ (IFN-γ) content ($P<0.05$), and 0.30% supplementation significantly increased serum interleukin-10 (IL-10) content ($P<0.05$). Yeast cell wall polysaccharide had no significant effects on serum interleukin-2 (IL-2), interleukin-6 (IL-6), or tumor necrosis factor-α (TNF-α) contents ($P>0.05$). (3) Compared with the control group, 0.30% and 0.45% yeast cell wall polysaccharide supplementation significantly increased ileal CD4+ lymphocyte content ($P<0.05$), while dietary yeast cell wall polysaccharide tended to increase ileal CD8+ and CD20+ lymphocyte contents, though the differences were not significant ($P>0.05$). These findings indicate that yeast cell wall polysaccharide can enhance peripheral blood and gut immunity in weaned piglets and alleviate weaning stress.

Keywords: yeast cell wall polysaccharide; weaned piglets; immunoglobulin; lymphocytes

Introduction

Weaning is a critical stage in piglet production. After weaning, piglets face changes in diet and living environment, coupled with underdeveloped digestive and immune functions, leading to reduced growth performance, increased diarrhea rates, intestinal villus atrophy, and imbalanced gut microbiota. Previously, antibiotics were added to diets to address weaning stress-related problems. However, the development of bacterial resistance due to antibiotic use has become a serious concern, making the development of antibiotic alternatives urgent. Prebiotics and probiotics have shown promising results as antibiotic replacements. Using yeast and yeast derivatives as feed additives promotes healthy animal growth and improves growth performance and beneficial gut bacteria content in livestock. Previous animal trials found that dietary supplementation with less than 0.15% yeast cell wall polysaccharide showed no obvious effects, while supplementation with 0.15%, 0.30%, and 0.45% significantly improved average daily gain and average daily feed intake in weaned piglets, with a tendency to reduce feed-to-gain ratio and diarrhea rates. Yeast cell wall polysaccharide primarily contains mannan oligosaccharides and β-glucan, which have immunomodulatory effects in livestock. To further understand the effects of yeast cell wall polysaccharide on the immune mechanisms of weaned piglets, this study investigated its effects on serum immunoglobulins, cytokines, and ileal lymphocyte content to elucidate its mechanisms of action on peripheral blood and gut immunity.

Materials and Methods

1.1 Experimental Material

The yeast cell wall polysaccharide was derived from brewer' s yeast cell walls, obtained from Top Biological Technology Co., Ltd. Its main components were mannan oligosaccharide (23.45%) and β-glucan (39.24%), with crude protein content of 26.30%, crude ash of 3.30%, and moisture content of 5.35%.

1.2 Experimental Animals and Design

A single-factor experimental design was employed. A total of 180 piglets weaned at 21 days of age with similar genetic background, parity, and body weight were randomly divided into 4 groups, with 5 replicates per group and 9 piglets per replicate. The four groups were fed experimental diets supplemented with 0 (control), 0.15%, 0.30%, and 0.45% yeast cell wall polysaccharide, respectively. The experimental period lasted 21 days.

1.3 Experimental Diets

Piglets were fed corn-soybean meal-based experimental diets without antibiotics. Diet formulation followed NRC (2012) and Chinese Feeding Standards for Swine (2004). The composition and nutrient levels of experimental diets are shown in Table 1 .

Table 1 Composition and nutrient levels of experimental diets (air-dry basis) %

Items	Yeast cell wall polysaccharide level/%			
Ingredients	0	0.15	0.30	0.45
Expanded corn	30.00	30.00	30.00	30.00
Broken rice	20.00	20.00	20.00	20.00
Flour	10.00	10.00	10.00	10.00
Rice bran	5.00	5.00	5.00	5.00
Expanded soybean	10.00	10.00	10.00	10.00
FSBM	8.00	8.00	8.00	8.00
Imported fish meal	3.00	3.00	3.00	3.00
FSPC	2.00	2.00	2.00	2.00
White sugar	3.00	3.00	3.00	3.00
Whey powder	5.00	5.00	5.00	5.00
Coconut oil meal (50%)	1.00	1.00	1.00	1.00
$CaHPO_4$	1.00	1.00	1.00	1.00
Limestone	0.80	0.80	0.80	0.80
NaCl	0.30	0.30	0.30	0.30
Lysine · HCl	0.40	0.40	0.40	0.40
Choline chloride (50%)	0.10	0.10	0.10	0.10
Threonine	0.10	0.10	0.10	0.10
DL-Methionine	0.10	0.10	0.10	0.10
Yeast cell wall polysaccharide	0.00	0.15	0.30	0.45
Premix[1]	0.20	0.20	0.20	0.20
Total	100.00	100.00	100.00	100.00
Nutrient levels[2]				
DE/(MJ/kg)	14.50	14.50	14.50	14.50
CP	20.00	20.00	20.00	20.00
Ca	0.80	0.80	0.80	0.80
TP	0.65	0.65	0.65	0.65
AP	0.45	0.45	0.45	0.45
Lys	1.35	1.35	1.35	1.35
Met+Cys	0.74	0.74	0.74	0.74
Thr	0.85	0.85	0.85	0.85

[1] The premix provided the following per kilogram of diet: VA 6,350 IU, VD_3 2,150 IU, VE 25 IU, VK 3 mg, VB_1 1.8 mg, VB_{12} 0.024 mg, riboflavin 6 mg, folic acid 0.9 mg, biotin 4.5 mg, niacin 24 mg, pantothenic acid 20 mg, Zn 80 mg, Fe 150 mg, Cu 10 mg, I 0.6 mg, Se 0.5 mg, Co 0.8 mg.

[2] Nutrient levels were calculated values.

1.4 Animal Management

Piglets were housed in nursery pens equipped with elevated slatted floors and nipple drinkers. The pig house was thoroughly cleaned and disinfected before the experiment. During the trial, piglets were fed 4-5 times daily with ad libitum access to feed and water. Other management practices and immunization procedures followed the farm' s routine protocols.

1.5 Sample Collection and Processing

On day 21 of the experiment, one piglet with body weight close to the replicate average was randomly selected from each replicate for fasting blood collection from the anterior vena cava. Blood was placed in non-anticoagulant tubes, allowed to clot at room temperature, then centrifuged at 3,000 r/min for 5 min at 4 °C. The serum was collected and stored at -20 °C for subsequent analysis.

Piglets were anesthetized by intramuscular injection of 4% sodium pentobarbital solution. After complete anesthesia, they were euthanized by jugular exsanguination. The abdominal cavity was opened, and ileal segments were rapidly excised, rinsed in ice-cold physiological saline to remove contents, then fixed in 4% paraformaldehyde for 24 h.

1.6 Analytical Methods

1.6.1 Determination of Serum Immunoglobulin and Cytokine Contents Enzyme-linked immunosorbent assay (ELISA) was used to determine serum contents of immunoglobulin G (IgG), immunoglobulin M (IgM), immunoglobulin A (IgA), interleukin-2 (IL-2), interleukin-6 (IL-6), interleukin-10 (IL-10), interferon-γ (IFN-γ), and tumor necrosis factor-α (TNF-α).

1.6.2 Paraffin Immunohistochemical Sections of Ileal CD4+, CD8+, and CD20+ Lymphocytes 1.6.2.1 Conventional Paraffin Section Preparation

Ileal tissues fixed in 4% paraformaldehyde for over 24 h were trimmed to appropriate size, then subjected to routine dehydration, clearing, paraffin embedding, and sectioning (4 m). Sections were mounted on poly-L-lysine-coated slides, dried on a slide warmer, then baked at 55 °C for 20 min to prevent detachment.

1.6.2.2 Immunohistochemical Staining Procedure

1. After routine deparaffinization and rehydration, sections were incubated with 3% hydrogen peroxide (H_2O_2) in deionized water for 10 min in a humidified chamber to block endogenous peroxidase activity.
2. Sections were washed 3 times with phosphate-buffered saline (PBS) (pH 7.4) for 5 min each.
3. Antigen retrieval was performed with EDTA in a 95 °C water bath for 12 min.

4. After cooling to room temperature, sections were washed 3 times with PBS (pH 7.4) for 5 min each.
5. PBS was removed, and normal goat serum blocking solution was applied to cover the tissue sections and incubated for 10-12 min in a humidified chamber, then drained without washing.
6. Primary antibodies were added and incubated overnight at 4 °C. Primary antibodies (Abcam) were: Anti-CD4 antibody [EPR6855] ab133616, Anti-CD8 antibody ab4055, and Anti-CD20 antibody [EP459Y] ab78237.
7. Sections were washed 3 times with PBS (pH 7.4) for 5 min each.
8. PBS was removed, and biotin-labeled goat anti-rabbit IgG was applied to cover the tissue sections and incubated for 10-12 min in a humidified chamber.
9. Sections were washed 3 times with PBS (pH 7.4) for 5 min each.
10. PBS was removed, and horseradish peroxidase-labeled streptavidin working solution was applied to cover the tissue sections and incubated for 10-12 min in a humidified chamber.
11. Sections were washed 3 times with PBS (pH 7.4) for 5 min each.
12. PBS was removed, and diaminobenzidine (DAB) working solution was applied for 2-5 min, allowing the peroxidase to react and produce brown staining. Sections were rinsed 3 times with distilled water for 5 min each.
13. Sections were counterstained with hematoxylin for 2-3 min, then rinsed 3 times with distilled water for 5 min each.
14. Sections were dehydrated through graded alcohols, cleared with xylene, and mounted with neutral balsam.

Negative controls were included in each assay by substituting primary antibody with 0.01 mol/L PBS (pH 7.4), with all other steps remaining the same.

1.6.2.3 Observation of Immune-Related Cells in Intestinal Tissues

Image-pro Plus 6.0 software was used to measure the integrated optical density (IOD) and total target area (Area) of positive cells per field of view. More than 30 fields were measured per section, and mean optical density (IOD/Area) was calculated to reflect lymphocyte content.

1.7 Data Processing and Statistical Analysis

All data were initially processed using Excel 2003, then analyzed using one-way ANOVA in SPSS 17.0 software. Results are expressed as "mean ± standard error." Differences were considered significant at $P<0.05$, and trends were noted at $0.05 \leq P<0.10$.

Results

2.1 Effects of Yeast Cell Wall Polysaccharide on Serum Immunoglobulin and Cytokine Contents in Weaned Piglets

As shown in Table 2 , compared with the control group, dietary supplementation with 0.15%, 0.30%, and 0.45% yeast cell wall polysaccharide significantly increased serum IgA content by 15.04%, 20.35%, and 13.27%, respectively (P<0.05). Supplementation with 0.30% and 0.45% yeast cell wall polysaccharide significantly increased serum IgG content (P<0.05). Dietary yeast cell wall polysaccharide had no significant effect on serum IgM content (P>0.05).

Compared with the control group, dietary supplementation with 0.15%, 0.30%, and 0.45% yeast cell wall polysaccharide significantly decreased serum IFN-γ content by 34.94%, 29.13%, and 29.22%, respectively (P<0.05). Supplementation with 0.30% yeast cell wall polysaccharide significantly increased serum IL-10 content (P<0.05). Yeast cell wall polysaccharide had no significant effects on serum IL-2, IL-6, or TNF-α contents (P>0.05), though there was a trend toward increased IL-2 content (P=0.071).

Table 2 Effects of yeast cell wall polysaccharide on content of immunoglobulin and cytokine in serum of weaned piglets

Items	Yeast cell wall polysaccharide level/%				P-value
	0	0.15	0.30	0.45	
Immunoglobulin/(g/L)					
IgA	1.13$±0.07^b	1.30±0.02^a	1.36±0.02^a	1.28±0.[illegible]	0.05||IgM|2.35±0.06|2.43±0.01|2.47±0.02|2.45±0.01|$F>$ $
	0.05||IgG|20.62±0.39^c	21.13±0.17^{bc}	22.28±0.34^a	21.69±0.23^{ab}	<
	0.05||$**Cytokine/(pg/mL)**$||||||$IL-$				
	2|32.23±0.85|40.77±3.63|39.28±0.84|38.35±1.28|0.071||$IL-$				
	6|115.67±6.24|129.14±8.05|111.19±0.97|110.43±1.43| >				
	0.05||$IL-$				
	10|21.09±1.23^b|28.92±1.41^b|38.76±3.42^a|25.77±3.01^b| <				
	0.05||$IFN-$ $				

In the same row, values with different small letter superscripts mean significant difference (P<0.05), while with the same or no letter superscripts mean no significant difference (P>0.05).

2.2 Effects of Yeast Cell Wall Polysaccharide on Ileal CD4+, CD8+, and CD20+ Lymphocyte Contents in Weaned Piglets

Figure 1 [Figure 1: see original paper] shows immunohistochemical sections of CD4+ lymphocytes in the ileal lamina propria of weaned piglets, with brown/reddish-brown cells representing CD4+ lymphocytes. Figure 2 [Figure

2: see original paper] shows CD4+ lymphocytes in the ileal villus lamina propria, revealing that CD4+ helper T lymphocytes increased markedly with increasing dietary yeast cell wall polysaccharide levels. To further quantify these results, Image-pro Plus 6.0 software was used to measure mean optical density of positive cells per unit area. As shown in Figure 3 [Figure 3: see original paper], compared with the control group, dietary supplementation with 0.30% and 0.45% yeast cell wall polysaccharide significantly increased ileal CD4+ lymphocyte content ($P<0.05$), with mean optical density values within the normal range.

Brown/reddish-brown indicates positive cell staining (DAB chromogen), counterstained with hematoxylin-eosin (HE). All sections magnified at 400×. A: control group, B: 0.15% yeast cell wall polysaccharide group, C: 0.30% yeast cell wall polysaccharide group, D: 0.45% yeast cell wall polysaccharide group. The same applies below.

Figure 4 [Figure 4: see original paper] shows immunohistochemical sections of CD8+ lymphocytes (cytotoxic T cells) in the aggregated lymphoid nodules of ileal lamina propria. Cytotoxic T cell content showed little difference among groups and was lower than CD4+ lymphocyte content. Figure 5 [Figure 5: see original paper] shows CD8+ lymphocytes in Peyer' s patches of ileal villi. Mean optical density values measured using Image-pro Plus 6.0 software revealed no significant differences in CD8+ lymphocyte content among groups ($P>0.05$).

Figure 7 [Figure 7: see original paper] shows immunohistochemical sections of CD20+ lymphocytes in Peyer' s patches of weaned piglet ileum, with brown/reddish-brown cells representing CD20+ lymphocytes. CD20+ lymphocytes were found exclusively in intestinal Peyer' s patches, which also contained small numbers of T lymphocytes. Mean optical density values measured using Image-pro Plus 6.0 software showed no significant differences in CD20+ lymphocyte content among groups ($P>0.05$).

Discussion

3.1 Effects of Yeast Cell Wall Polysaccharide on Serum Immunoglobulin Content in Weaned Piglets

Immunoglobulins include antibodies and membrane immunoglobulins. Membrane immunoglobulins function as antigen receptors with specific antigen recognition capabilities. Antibodies are primarily present in body fluids, especially serum. Serum immunoglobulin content reflects the status of humoral immunity to some extent. The main immunoglobulins in serum are IgA, IgM, and IgG. IgM is the primary antibody in initial immune responses, while IgG is the main antibody mediating humoral immunity, playing important roles in antibacterial and antiviral defense. Due to the special structure of the sow placenta, macromolecules cannot pass through to the fetus, so newborn piglets acquire immunoglobulins almost exclusively from colostrum. However, gut closure in piglet intestinal mucosa (occurring 24-36 h after birth) blocks immunoglobulin

entry into blood circulation via pinocytosis. Numerous studies have found that early weaning stress decreases serum immunoglobulin content and suppresses antibody synthesis capacity. Dietary yeast culture supplementation has been shown to significantly increase serum IgG and IgM contents in piglets. Yue et al. reported that dietary mannan oligosaccharide supplementation also significantly increased serum IgG content in weaned piglets. These findings align with our results, where 0.30% and 0.45% yeast cell wall polysaccharide supplementation significantly increased serum IgG content, though IgM content was not significantly affected. IgA is primarily synthesized and secreted by plasma cells in the intestinal lamina propria before entering blood circulation. Mannan oligosaccharide in yeast cell wall polysaccharide plays an important role in increasing serum IgA content. This study found that dietary yeast cell wall polysaccharide significantly increased serum IgA content in weaned piglets.

3.2 Effects of Yeast Cell Wall Polysaccharide on Serum Cytokine Content in Weaned Piglets

Cytokines are peptides or protein molecules synthesized and secreted by immune and some non-immune cells that regulate cellular functions. They are present at low concentrations but have highly efficient effects, playing important roles in physiological processes such as cell growth, differentiation, and apoptosis, as well as in pathological processes including acute and chronic inflammation. Helper T cells (Th) are divided into Th1 and Th2 cells. IL-2, IFN-γ, and TNF-α are cytokines secreted by Th1 cells, while IL-6 and IL-10 are secreted by Th2 cells. IL-2 primarily promotes differentiation and proliferation of B cells and natural killer (NK) cells, thereby promoting immunoglobulin production. IL-10 can inhibit production of IL-1, IL-6, and TNF-α to some extent, while enhancing B cell proliferation and antibody production. IL-6 is a key regulator of acute-phase responses, promotes differentiation of B and T cells, and inhibits inflammatory responses by suppressing IL-1 and TNF-α actions.

Most studies have demonstrated an inseparable link between yeast cell wall components and immune function. As early as 1987, Seljelid et al. found that β-glucan could stimulate macrophage activity in mice. Subsequently, Djeraba et al. reported that mannan oligosaccharide could activate chicken macrophages. Shen et al. found that yeast culture supplementation increased expression of the Th1 cytokine IFN-γ in the intestine. However, our study found that yeast cell wall polysaccharide decreased serum IFN-γ content in weaned piglets. This discrepancy may be due to differences in weaning age between studies—28-day-old versus 21-day-old piglets have different intestinal development status and may respond differently to products. Additionally, the product types and supplementation levels differed between studies. Shen et al. used yeast culture, while our study used yeast cell wall polysaccharide with different potencies of mannan oligosaccharide and glucan. Our study also found that 0.30% yeast cell wall polysaccharide supplementation significantly increased serum IL-10 content, consistent with findings by Li and Kawashima et al. Furthermore, some studies

have found that β(1-3)(1-6)-D-glucan supplementation significantly increased serum IL-2 content and downregulated serum TNF-α content after lipopolysaccharide (LPS) stimulation. However, our study found no significant effects on serum IL-2, IL-6, or TNF-α contents, though there was a trend toward increased IL-2. Overall, yeast cell wall polysaccharide may promote the transition of T cells from Th1 to Th2 type.

3.3 Effects of Yeast Cell Wall Polysaccharide on Ileal CD4+, CD8+, and CD20+ Lymphocyte Contents in Weaned Piglets

Most lymphocytes in the body reside in the gastrointestinal tract and gut-associated lymphoid tissue. The small intestine contains more immune cells than the large intestine, particularly Peyer' s patches in the ileum. CD4+ lymphocytes are important immune cells primarily expressed on Th cells. CD8+ lymphocytes are another T lymphocyte subset, also known as cytotoxic T cells, which differentiate into effector and memory cytotoxic T cells upon antigen stimulation. CD8+ lymphocytes can specifically kill antigen-bearing target cells, and memory cytotoxic T cells have memory functions for antigenic targets. CD20+ lymphocytes are expressed on B lymphocytes at all stages except plasma cells. Upon antigen stimulation, they differentiate into numerous plasma cells that synthesize and secrete antibodies to exert humoral immune functions.

Previous studies found that under stress conditions, dietary yeast cell wall product supplementation increased cecal lymph node T lymphocyte content in broilers and turkeys compared to control groups fed basal diets. Yeast culture significantly increased blood CD4+ lymphocyte content in LPS-challenged piglets. Our study found that 0.30% and 0.45% yeast cell wall polysaccharide supplementation significantly increased ileal CD4+ lymphocyte content in weaned piglets, with a non-significant increasing trend for ileal CD8+ and CD20+ lymphocyte contents. Sauerwein et al. reported that yeast cell wall components had no significant effects on CD4+ and CD8+ lymphocytes in ileal epithelial cells of finishing pigs, possibly because finishing pigs have well-developed defense systems. In contrast, weaned piglets experience weaning stress and have immature defense systems, making them more responsive to immune-enhancing effects of yeast cell wall polysaccharide.

The mechanisms by which yeast cell wall polysaccharide affects peripheral blood and gut immunity may involve several pathways. First, it improves intestinal CD4+ lymphocyte content, promoting the transition of helper T cells from Th1 to Th2 type, inhibiting IFN-γ production while promoting IL-10 production, thereby preventing excessive inflammatory responses. Additionally, increased serum IgG and IgA contents enhance humoral immunity. Considering results from previous animal trials and the current study on growth performance, intestinal health, and immune function, the appropriate supplementation level of yeast cell wall polysaccharide in weaned piglet diets is 0.30%.

Conclusions

1. Yeast cell wall polysaccharide modulates serum immunoglobulin content in piglets. Dietary supplementation with 0.30% and 0.45% yeast cell wall polysaccharide significantly increased serum IgG content, while 0.15%, 0.30%, and 0.45% supplementation significantly increased serum IgA content.

2. Yeast cell wall polysaccharide improves serum cytokine profiles in weaned piglets. Supplementation with 0.15%, 0.30%, and 0.45% yeast cell wall polysaccharide significantly decreased serum IFN-γ content, and 0.30% supplementation significantly increased serum IL-10 content.

3. Yeast cell wall polysaccharide modulates ileal lymphocyte populations. Dietary supplementation with 0.30% and 0.45% yeast cell wall polysaccharide significantly increased ileal CD4+ lymphocyte content in weaned piglets.

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Note: Figure translations are in progress. See original paper for figures.