

# FEEDING FERMENTED SOYBEAN MEAL IN PIGLETS- REVOLUTIONARY CONCEPT: A REVIEW

**G. Srinivasan\***

*Pulikulam Cattle Research Station  
Tamil Nadu Veterinary and Animal Sciences University  
Manamadurai, Tamil Nadu, India*

## ABSTRACT

*Fermentation of soybean meal eliminates the anti-nutritional factors of soybean meal making fermented soybean meal a potential lower-cost substitute for animal protein in piglet diets. Fermentation process using bacteria, fungal and yeast strains in soybean meal (SBM) is the novel technique which is used to remove the anti-nutritional factors of SBM. In general, two types of fermentation process namely Solid State Fermentation (SSF) and Liquid or Sub merged State Fermentation (SmF). Numerous studies were carried out to document the beneficial effects of feeding fermented soybean meal. Weaning is a stressful condition to the piglets which accompanied by diarrhoea, some time may lead to death. Antibiotic growth promoters can be added to the piglet diets but it is banned in most of the countries. Fermented soybean meal supplementation can enhance pig growth performance of which the enhancement in feed efficiency is due to the improvement in nutritional value and availability rather than feed intake. The gut microbiota plays a crucial role in livestock health and disease. Hence, it is necessary to find a mechanism to remove anti nutritional factors along with improved intestinal microbiota thereby producing improved production performance and reduced diarrhoea in piglets. The main objective of this review is to discuss the benefits of feeding fermented soybean meal in piglets.*

**Keywords:** Gut microbiota, Piglet diarrhoea, Solid state fermentation, Soybean meal, Weaning

Received : 09.02.2022

Revised : 27.05.2022

Accepted : 27.05.2022

## INTRODUCTION

Soybean is commonly used plant protein source in piglet diets due to presence of good amino acid profile, easily available and economical. It has some anti-nutritional factors which limits the soybean usage in piglet diets.

Soybean meal contains high concentration of trypsin inhibitor, serine protease inhibitor (Dunsford *et al.*, 1989; Li *et al.*, 1990). Anti-nutritional factor present in the soybean meal (SBM) affects the protein utilization and has detrimental effects on the small intestine (Dunsford *et al.*, 1989; Li *et al.*, 1990). Fermentation process using bacteria, fungal and yeast strains in soybean meal is the novel

\* Assistant Professor and Head, Corresponding author,  
Email: govvisri4@gmail.com

technique which is used to remove the anti-nutritional factors of SBM. Numerous studies were carried out to document the beneficial effects of feeding fermented soybean meal (FSBM) in both adult and young one of ruminants, non-ruminants (Mathivanan *et al.*, 2006; Song *et al.*, 2008; Yuan *et al.*, 2013).

New born piglets have limited ability to digest feeds and their immune system is also weak up to 6 weeks of age (Weiner *et al.*, 2015). Weaning piglets is also a stressful condition to the piglets which accompanied by diarrhoea or infection or some time may lead to death (Han *et al.*, 2016).

Antibiotic Growth Promoter (AGP) can be added to the diets to prevent diarrhoea or infection and to improve the health status of piglets. But, European Union and some other countries banned the use of AGP in feeds. Feeding probiotics alternative to antibiotics reduce diarrhoea and improve the health status by altering the intestinal microbiota but

addition of AGP or probiotic will not remove the anti-nutritional factors present in the feed ingredients. Hence, it is necessary to find a mechanism to remove anti nutritional factors along with improved intestinal microbiota there by producing improved production performance and reduced diarrhoea in piglets. Fermentation of SBM addresses all these issues. The main objective of this review is to discuss the benefits of feeding FSBM in piglet diets.

### Different types of fermentation process

There are two types of fermentation process namely Solid State Fermentation (SSF) and Liquid or Sub merged State Fermentation (SmF). Solid state fermentation takes place in solid matrix without or smaller quantities of free water. On the other hand, in sub merged fermentation the substrate is suspended in large volume of water. Fermentation process eliminates anti nutritional factors and improves the nutritional value of SBM.

### Difference in SSF and SmF

Features	SSF	SmF
Medium	Not free flowing	Free flowing
Nutrients	Solid substrate	Employed
Water	Medium absorbs	Medium is dissolved
Temperature and P <sup>H</sup>	Not uniform	Uniform
Contamination	Less	Higher
Product	Highly concentrated	Low concentration
Liquid waste	Not produced	High quantity produced

(Prabhakar *et al.*, 2005; Koyani and Rajput, 2015)

## Different types of fermentation

### Bacterial fermentation

There are different bacterial species used in bacterial fermentation of SBM. *Bacillus* species, *Lactobacillus* and *Clostridium* species are commonly used bacterial species in the fermentation process. Yuan *et al.* (2017) used *Bacillus subtilis*, *Hansenula anomala* and *Lactobacillus casei* in 2:1: 2 ratios for fermentation process. Zhu *et al.* (2017) used 10 per cent mixture of equal cell numbers of *Lactobacillus plantarum*, *B. subtilis* and yeast *Saccharomyces cerevisiae* to achieve 10<sup>8</sup> CFU/g in SBM. Cheng *et al.* (2019) used 3 per cent (v/w) inoculums containing *L. acidophilus*, *L. delbrueckii* and *L.salvarius* and *C. butyricum* for his studies. *Lactobacillus plantarum* is frequently used to ferment SBM (Amadou *et al.*, 2010a and 2010b; Amadou *et al.*, 2011). Fermentation using *B. subtilis* increased small size protein concentration with increased arginine, serine, threonine and aspartic acid but decreased proline content (Teng *et al.*, 2012).

### Fungal fermentation

Several species of genus *Aspergillus* and *Rhizopus* are being used for fermentation of SBM. Fermentation of SBM using fungus strain is well documented (Ilyas *et al.*, 1995; Hong *et al.*, 2004; Liu *et al.*, 2007). Kishida *et al.* (2000) used *A. awamori* strain for his studies. Fermentation with fungal strain eliminates trypsin inhibitor; almost completely eliminate phytate resulting in more available phosphorus (Ilyas *et al.*, 1995) and Zinc (Hirabayashi *et al.*, 1998). It also breaks down the carbohydrates like Stachyose, raffinose and

sucrose (Cervantes-Pahm and Stein, 2010). It also increases the breakdown of long chain protein to small size peptides (<15 kDa) in FSBM (Hirabayashi *et al.*, 1998). Apart from carbohydrate break down, crude protein, crude fibre and dry matter contents were increased (Feng *et al.*, 2007). The FSBM contains 10 per cent more crude protein than SBM (Hong *et al.*, 2004). The change in amino acid profile happens due to microbial metabolism that take place during fungal fermentation (Frias *et al.*, 2008).

### Yeast fermentation

Zhu *et al.* (2017) studied the effect of combination of *L. plantarum*, *B. subtilis* and *S. cerevisiae* in different levels of incubation on FSBM. He revealed that growth performance, immune function, intestinal health significantly improved in weaned piglets fed with 10 per cent FSBM. Song *et al.* (2008) revealed that immune reactivity of SBM significantly reduced, breakdown of large protein increased thereby increasing the smaller peptides. SBM ferments with *S. cerevisiae* significantly increased sulphur containing amino acid cysteine content which is low in SBM (Song *et al.*, 2008). This finding indicated that the choice of microorganism for fermentation is based on the nutritional requirement of the final fermented product.

### Growth performance in piglets

Zhu *et al.* (2017) compared the effect of SBM with 5, 10 and 15 per cent FSBM in the diets of piglets and revealed that piglets fed with 5 and 10 per cent FSBM shown significantly increased average daily weight gain compared to SBM fed group. Piglets

fed with 15 per cent FSBM had about half of this increase. Compared to SBM fed group, feed gain ratio decreased by 11.27 per cent in FSBM fed group. Importantly diarrhoea rate is significantly reduced in FSBM fed group. Cheng *et al.* (2019) studied the effect of replacement of 3 per cent fish meal with 5 per cent FSBM and reported that FSBM can replace fish meal. Yuan *et al.* (2017) studied that FSBM had positive effect on nutrient digestibility. They revealed that addition of 10 per cent FSBM produces higher average daily gain, feed conversion ratio compared to diet containing without FSBM. FSBM also reduces the diarrhoea rate compared to piglets fed with SBM.

In intestinal morphology villi height and crypt depth play a major role in nutrient absorption and it also acts as protective barrier. Piglets fed with FSBM shown significantly increased villi height at duodenum, jejunum and ileum and decreased crypt depth than control fed with SBM. The ratio to villi height to crypt depth was increased (Zhu *et al.*, 2017). Beneficial microbes present in the FSBM inhibit the pathogenic microbial proliferation and reduce the antigenic protein by microbial fermentation. The increase in average daily gain, average feed intake and feed conversion ratio were reported by Feng *et al.* (2007); Jones *et al.* (2010); Liu *et al.* (2007) and Hirabayashi *et al.* (1998). The growth performance of weaned piglets was increased due to elimination of antinutritional factors after fermentation (Hong *et al.*, 2004), decreased diarrhoea rate, improved palatability, enhanced feed utilization and better absorption of feed in the intestine. The improvement in the

nutrient utilization may be due to production of enzymes during microbial fermentation.

### **Reduction in anti-nutritional factors**

Reduction of anti-nutritional factors present in the SBM is the main advantage of fermentation. Majority of trypsin inhibitors found in soybean meal resides at 21.5 kDa. Hydrolysis of protein with fermentation with in this molecular weight range potentially decreases trypsin inhibitor contents in SBM.

### **Diarrhoea incidence**

Weaning is the one of the stressful conditions for the piglets which may cause diarrhoea in piglets apart from infection. Diarrhoea incidence has to be recorded daily throughout the experimental period by direct observation. The faecal consistency level 2 or 3 was described as diarrhoea (Liu *et al.*, 2010). Generally, diarrhoea incidence is calculated by

Diarrhoea incidence = No of piglets  
with diarrhoea X diarrhoea days X 100

Replacement of fish meal with FSBM did not affect the average daily weight gain and feed conversion ratio in weaning piglets compared to fish meal group (Cheng *et al.*, 2019). But FSBM fed group exhibited a lower incidence of diarrhoea compared to fish meal fed group. Higher level of fish meal in diet leads to high incidence of diarrhoea in weaned piglets (Wu *et al.*, 2015). Fish meal is highly fermentable in the intestine there by producing higher bacterial metabolites such as polyamine and ammonia (Wen *et al.*, 2018). Higher levels of these bacterial metabolites are the main reason for diarrhoea in piglets (Porter and Kenworthy, 1969). Several studies

demonstrated that fish meal can be completely replaced with FSBM without affecting the growth performance (Yun *et al.*, 2005; Rojas and Stein, 2015). Partial replacement of fish meal with FSBM has no negative effects on growth performance in weaning piglets (Jeong and Kim, 2015).

Zhu *et al.* (2018) revealed that no significant difference between FSBM fed group and control group in major genera species found during faecal analysis. But significant difference noticed in less abundance species in faecal sample. The data revealed that relative abundance of *Clostridium sensu strict 01*, *Lactobacillus*, *Lachnospira* and *Bacteroides* species were closely related to diarrhoea which is low in FSBM fed group. Zhu *et al.* (2017) reported that diarrhoea rate is significantly reduced in FSBM fed group than SBM fed group. More production of lactic acid in FSBM fed group creates acidic environment in the intestine inhibit the growth of pathogens responsible for the diarrhoea and prevent diarrhoea incidence (Su *et al.*, 2018).

### **Serum biochemical characteristics**

Zhu *et al.* (2017) revealed that no significant difference noticed in total calcium phosphorus, serum aspartate transaminase between FSBM and control diet fed group. But piglets fed with FSBM had higher level of acid phosphatase, total protein, albumin and total globulin compared to control group. Chiang *et al.* (2009) and Shi *et al.* (2016) have also reported the same. ALP affects fat absorption, hydrolysis of monophosphate ester and transcellular solute transport. These are correlated with digestive and absorptive functions in the intestinal tract. Serum glucose

level was significantly high in 10% and 15% FSBM fed group than control group but in 5% FSBM fed group serum glucose level did not differ significantly. The serum urea nitrogen was reduced by 20 per cent in FSBM fed group than control group. The decreased urea nitrogen indicates that fermentation process altered the nitrogen distribution within the feed ingredients.

### **Immune characteristics**

Serum immunoglobulin concentration indicates the immune status of the piglets. Deng *et al.* (2013) reported that inclusion of *B. subtilis* and *L. salivarius* increases intestinal IgA producing cells. *B. subtilis* and *B. licheniformis* promotes serum IgG production (Ahmed *et al.*, 2014). Zhu *et al.* (2017) reported that FSBM supplementation significantly increases IgG, IgM and IgA levels in the weaned piglets. Cheng *et al.* (2019) reported that FSBM fermented with *Lactobacillus* species and *C. butyricum* potentiate the immunity of piglets by increasing serum IgG and IgA levels compared to fish meal fed group. Zhu *et al.* (2017) reported that IgM, lymphocyte and WBC levels were increased by 55.03%, 48.81% and 14.32% respectively compared to control group fed with SBM. In contrast, Yuan *et al.* (2017) reported that dietary FSBM did not affect the plasma immunoglobulin level. The serum immunoglobulin levels vary depends on the microbes used for the fermentation of SBM.

### **Conclusion**

Addition of FSBM in the diets of piglets improves the nutrient digestibility, utilization, absorption of nutrients there by improves the growth performance of piglets.

Similar to antibiotic growth promoters FSBM reduces the incidence of diarrhoea. Hence, it is concluded that FSBM can be replaced with soybean meal or fish meal in piglet diets to improve the production performance of the piglets.

## REFERENCES

- Ahmed, S.T., Hoon, J., Mun, H.S. and Yang, C.J. (2014). Evaluation of *Lactobacillus* and *Bacillus*-based probiotics as alternatives to antibiotics in enteric microbial challenged weaned piglets. *African Journal of Microbiology Research*, **8**(1):96-104.
- Amadou, I., Amza, T., Foh, M.B.K., Kamara, M.T. and Le, G.W. (2010 a). Influence of *Lactobacillus plantarum* Lp6 fermentation on the functional properties of soybean protein meal. *Emirates Journal of Food and Agriculture*, **6**:456-465.
- Amadou, I., Kamara, M.T., Tidjani, A., Foh, M.B.K. and Le, G.W. (2010 b). Physicochemical and nutritional analysis of fermented soybean protein meal by *Lactobacillus plantarum* Lp6. *World Journal Dairy and Food Sciences*, **5**(2):114-118.
- Amadou, I., Le, G.W., Shi, Y.H. and Jin, S. (2011). Reducing, radical scavenging, and chelation properties of fermented soy protein meal hydrolysate by *Lactobacillus plantarum* Lp6. *International Journal of Food Properties*, **14**(3):654-665.
- Cervantes-Pahm, S.K. and Stein, H.H. (2010). Ileal digestibility of amino acids in conventional, fermented, and enzyme-treated soybean meal and in soy protein isolate, fish meal, and casein fed to weanling pigs. *Journal of Animal Sciences*, **88**(8):2674-2683.
- Cheng, Y.H., Su, L.W., Horng, Y.B. and Yu, Y.H. (2019). Effects of soybean meal fermented by *Lactobacillus* species and *Clostridium butyricum* on growth performance, diarrhoea incidence, and faecal bacteria in weaning piglets. *Annals of Animal Science*, **19**(4):1051-1062.
- Chiang, G., Lu, W.Q., Piao, X.S., Hu, J.K., Gong, L.M. and Thacker, P.A. (2009). Effects of feeding solid-state fermented rapeseed meal on performance, nutrient digestibility, intestinal ecology and intestinal morphology of broiler chickens. *Asian-Australasian Journal of Animal Science*, **23**(2):263-271.
- Deng, J., Li, Y., Zhang, J. and Yang, Q. (2013). Co-administration of *Bacillus subtilis* RJGP16 and *Lactobacillus salivarius* B1 strongly enhances the intestinal mucosal immunity of piglets. *Research in Veterinary Science*, **94**(1):62-68.
- Dunsford, B.R., Knabe, D.A. and Haensly, W.E. (1989). Effect of dietary soybean meal on the microscopic anatomy of the small intestine in the early-weaned pig. *Journal of Animal Sciences*, **67**(7):1855-1863.

- Feng, J., Liu, X., Xu, Z.R., Lu, Y.P. and Liu, Y.Y. (2007). The effect of *Aspergillus oryzae* fermented soybean meal on growth performance, digestibility of dietary components and activities of intestinal enzymes in weaned piglets. *Animal Feed Science and Technology*, **134**(3-4):295-303.
- Frias, J., Song, Y.S., Martínez-Villaluenga, C., De Mejia, E.G. and Vidal-Valverde, C. (2008). Immunoreactivity and amino acid content of fermented soybean products. *Journal of Agricultural and Food Chemistry*, **56**(1):99-105.
- Han, M., Song, P., Huang, C., Rezaei, A., Farrar, S., Brown, M.A. and Ma, X. (2016). Dietary grape seed proanthocyanidins (GSPs) improve weaned intestinal microbiota and mucosal barrier using a piglet model. *Oncotarget*, **7**(49):803-813.
- Hirabayashi, M., Matsui, T., Yano, H. and Nakajima, T. (1998). Fermentation of soybean meal with *Aspergillus usamii* reduces phosphorus excretion in chicks. *Poultry science*, **77**(4):552-556.
- Hong, K.J., Lee, C.H. and Kim, S.W. (2004). *Aspergillus oryzae* GB-107 fermentation improves nutritional quality of food soybeans and feed soybean meals. *Journal of Medicinal Food*, **7**(4):430-435.
- Ilyas, A., Hirabayasi, M., Matsui, T., Yano, H., Yano, F., Kikishima, T., Takebe, M. and Hayakawa, K. (1995). A note on the removal of phytate in soybean meal using *Aspergillus usamii*. *Asian-Australasian Journal of Animal Sciences*, **8**(2):135-138.
- Jeong, J.S. and Kim, I.H. (2015). Comparative efficacy of up to 50% partial fish meal replacement with fermented soybean meal or enzymatically prepared soybean meal on growth performance, nutrient digestibility and faecal microflora in weaned pigs. *Animal Science Journal*, **86**(6):624-633.
- Jones, C.K., DeRouche, J.M., Nelssen, J.L., Tokach, M.D., Dritz, S.S. and Goodband, R.D. (2010). Effects of fermented soybean meal and specialty animal protein sources on nursery pig performance. *Journal of Animal Science*, **88**(5):1725-1732.
- Kishida, T., Ataki, H., Takebe, M. and Ebihara, K. (2000). Soybean meal fermented by *Aspergillus wamori* increases the cytochrome p-450 content of the liver microsomes of mice. *Journal of Agricultural and Food Chemistry*, **48**(4):1367-1372.
- Koyani, R.D. and Rajput, K.S. (2015). Solid state fermentation: comprehensive tool for utilization of lignocellulosic through biotechnology. *Journal of Bioprocess Biotechnology*, **5**(258):1-15.
- Li, D.F., Nelssen, J.L., Reddy, P.G., Blecha, F., Hancock, J.D., Allee, G.L., Goodband, R.D. and Klemm, R.D. (1990). Transient hypersensitivity to soybean

- meal in the early-weaned pig. *Journal of Animal Science*, **68**(6):1790-1799.
- Liu, P.P.X.S., Piao, X.S., Thacker, P.A., Zeng, Z.K., Li, P.F., Wang, D. and Kim, S.W. (2010). Chito-oligosaccharide reduces diarrhoea incidence and attenuates the immune response of weaned pigs challenged with *Escherichia coli* K88. *Journal of Animal Science*, **88**(12):3871-3879.
- Liu, X., Feng, J., Xu, Z., Lu, Y. and Liu, Y. (2007). The effects of fermented soybean meal on growth performance and immune characteristics in weaned piglets. *Turkish Journal of Veterinary and Animal Sciences*, **31**(5):341-345.
- Mathivanan, R., Selvaraj, P. and Nanjappan, K. (2006). Feeding of fermented soybean meal on broiler performance. *International Journal of Poultry Science*, **5**(9):868-872.
- Porter, P. and Kenworthy, R. (1969). A study of intestinal and urinary amines in pigs in relation to weaning. *Research in Veterinary Science*, **10**(5):440-447.
- Prabhakar, A., Krishnaiah, K., Janaun, J. and Bono, A. (2005). An overview of engineering aspects of solid state fermentation. *Malaysian Journal of Microbiology*, **1**(2):10-16.
- Rojas, O.J. and Stein, H. (2015). Effects of replacing fish, chicken, or poultry by-product meal with fermented soybean meal in diets fed to weanling pigs. *Revista Colombiana de Ciencias Pecuarias*, **28**(1):22-41.
- Shi, C., He, J., Wang, J., Yu, J., Yu, B., Mao, X., Zheng, P., Huang, Z. and Chen, D. (2016). Effects of *Aspergillus niger* fermented rapeseed meal on nutrient digestibility, growth performance and serum parameters in growing pigs. *Animal Science Journal*, **87**(4):557-563.
- Song, Y.S., Frías, J., Martínez-Villaluenga, C., Vidal-Valverde, C. and de Mejía, E.G. (2008). Immunoreactivity reduction of soybean meal by fermentation, effect on amino acid composition and antigenicity of commercial soy products. *Food Chemistry*, **108**(2):571-581.
- Su, L.W., Cheng, Y.H., Hsiao, F.S.H., Han, J.C. and Yu, Y.H. (2018). Optimization of mixed solid-state fermentation of soybean meal by *Lactobacillus* species and *Clostridium butyricum*. *Polish Journal of Microbiology*, **67**(3):297-305.
- Teng, D., Gao, M., Yang, Y., Liu, B., Tian, Z. and Wang, J. (2012). Bio-modification of soybean meal with *Bacillus subtilis* or *Aspergillus oryzae*. *Biocatalysis and Agricultural Biotechnology*, **1**(1):32-38.
- Weiner, M.L., Ferguson, H.E., Thorsrud, B.A., Nelson, K.G., Blakemore, W.R., Zeigler, B., Cameron, M.J., Brant, A., Cochrane, L., Pellerin, M. and Mahadevan, B. (2015). An infant formula toxicity and toxicokinetic feeding study on carrageenan in preweaning piglets with special

- attention to the immune system and gastrointestinal tract. *Food and Chemical Toxicology*, **77**:120-131.
- Wen, X., Wang, L., Zheng, C., Yang, X., Ma, X., Wu, Y., Chen, Z. and Jiang, Z. (2018). Faecal scores and microbial metabolites in weaned piglets fed different protein sources and levels. *Animal Nutrition*, **4**(1):31-36.
- Wu, Y., Jiang, Z., Zheng, C., Wang, L., Zhu, C., Yang, X., Wen, X. and Ma, X. (2015). Effects of protein sources and levels in antibiotic-free diets on diarrhoea, intestinal morphology, and expression of tight junctions in weaned piglets. *Animal Nutrition*, **1**(3):170-176.
- Yuan, L., Chang, J., Yin, Q., Lu, M., Di, Y., Wang, P., Wang, Z., Wang, E. and Lu, F. (2017). Fermented soybean meal improves the growth performance, nutrient digestibility, and microbial flora in piglets. *Animal Nutrition*, **3**(1):19-24.
- Yuan, Y.C., Lin, Y.C., Yang, H.J., Gong, Y., Gong, S.Y. and Yu, D.H. (2013). Evaluation of fermented soybean meal in the practical diets for juvenile Chinese sucker, *Myxocyprinus asiaticus*. *Aquaculture Nutrition*, **19**(1):74-83.
- Yun, J.H., Kwon, I.K., Lohakare, J.D., Choi, J.Y., Yong, J.S., Zheng, J., Cho, W.T. and Chae, B.J. (2005). Comparative efficacy of plant and animal protein sources on the growth performance, nutrient digestibility, morphology and caecal microbiology of early-weaned pigs. *Asian-Australasian Journal of Animal Sciences*, **18**(9):1285-1293.
- Zhu, J., Gao, M., Zhang, R., Sun, Z., Wang, C., Yang, F., Huang, T., Qu, S., Zhao, L., Li, Y. and Hao, Z. (2017). Effects of soybean meal fermented by *L. plantarum*, *B. subtilis* and *S. cerevisiae* on growth, immune function and intestinal morphology in weaned piglets. *Microbial cell factories*, **16**(1):1-10.
- Zhu, J.J., Gao, M.X., Song, X.J., Zhao, L., Li, Y.W. and Hao, Z.H. (2018). Changes in bacterial diversity and composition in the faeces and colon of weaned piglets after feeding fermented soybean meal. *Journal of Medical Microbiology*, **67**(8):1181-1190.