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BENEFITS OF USING FERMENTATION TECHNOLOGY IN PIG FEEDS – FOCUS ON GUT HEALTH AND PERFORMANCE

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ABSTRACT

The future of modern animal husbandry is strongly influenced by several important global issues: 1) 'One Health', 2) growing world population, and 3) climate change and environmental degradation. Although progress has already been made in recent decades, more will need to be done in the coming decade(s) to meet the goals set. For future-proof animal husbandry, it is necessary to work with healthy animals, which feel well and need (almost) no antibiotics, and convert raw materials into animal protein (meat, milk, eggs) as efficiently as possible. And preferably raw materials that humans do not want to and/or cannot consume, and raw materials with the lowest possible carbon footprint. Microbial fermentation of raw materials before they are fed to animals, can play a decisive role in addressing the challenges mentioned above. The purpose of this article is to briefly describe microbial fermentation of raw materials and their effect on animal health and feed efficiency.

INTRODUCTION

Since their discovery in 1928, antibiotics have become a common way to treat infections caused by bacteria, fungi, and other microbes. While antibiotics are helpful to us, the tendency to overprescribe them is one of the reasons why the world is facing a crisis of treatment-resistant bacteria. Antimicrobial resistance (AMR) occurs when viruses, bacteria, fungi and parasites do not respond to antimicrobial treatments in humans and animals, thus allowing the survival of the microorganism within the host. A growing number of studies have shifted their attention from human factors to more serious contributing AMR factors arising from animal aspects. AMR has now emerged as a chronic public health problem globally, with the forecast of 10 million deaths per year globally by 2050 (O'Neil, 2016; Murray, 2022). 'One Health' is an integrated, unifying approach to balance and optimize the health of people, animals and the environment (Figure 1).

In the "One Health approach", attention is also paid to limiting the use of antibiotics in livestock farming, from which some of the resistant bacteria originate. Earlier research indicated that 73% of all antibiotics used worldwide are applied in farm animals, largely for food production (Van Boekel et al., 2019). This has already led to specific targets and requirements in European countries to achieve a substantial reduction in antibiotic use. The world's population is expected to increase from 7.3 billion in 2015 to 9.7 billion in

2050 (United Nations), which can be mainly attributed to growth in developing countries. To feed this growing population, food production would have to increase by 70% to 2050 (United Nations) and with this the demand for plant and animal products will increase sharply in the coming years. In addition, the projected increase in per capita income will further increase demand for foods that respond to higher incomes, such as livestock and dairy products, and vegetable oils. These livestock and dairy products are important sources of protein for humans, and plant-based ingredients are needed to produce such products. The subsequent increasing demand for proteins derived from plant-based ingredients, for both human food and animal feed, can lead to protein scarcity. There is therefore a need for a more efficient use of current ingredients and the search for alternative ingredients for humans and animals.

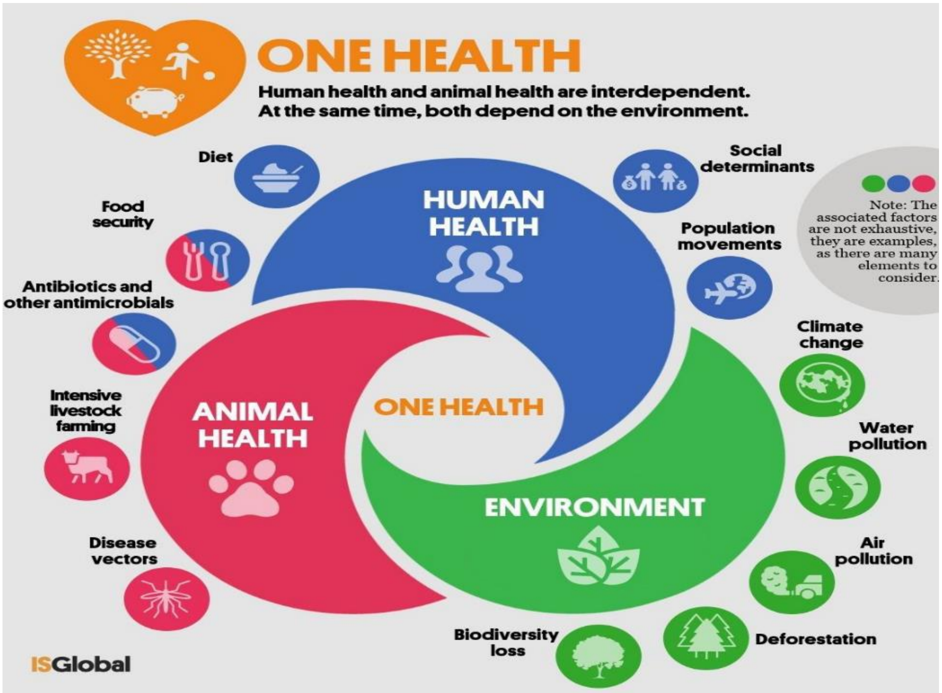


Figure 1 Interdependency of human and animal health (González, 2021)

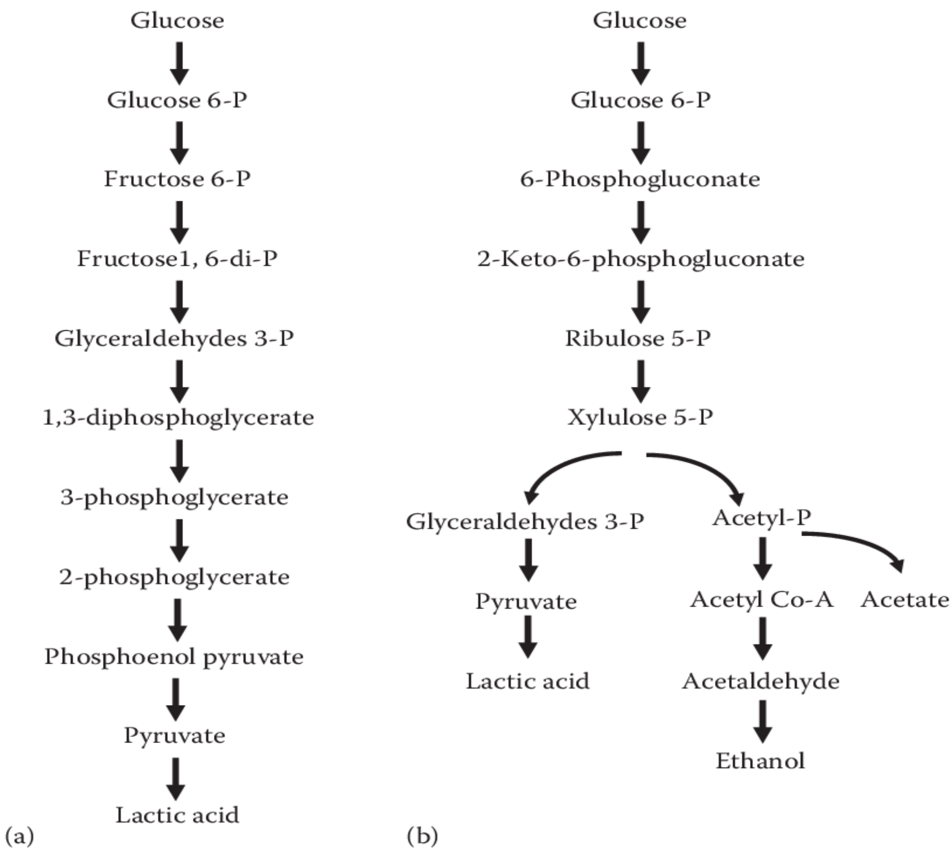
Climate change and environmental degradation are an existential threat to Europe and the world. The European Green Deal, approved in 2020, is a set of policy initiatives by the European Commission to make the European Union climate-neutral in 2050. Livestock supply chains account for 14.5% of global greenhouse gas emissions. Cattle (beef, milk) are responsible for about two-thirds of that total (FAO, 2017). To reduce greenhouse gas emissions, it is very important to maximize feed efficiency. An absolute prerequisite for this is that the animal is healthy and feels well. From this point of view, there are great opportunities for the use of fermented raw materials.

MICROBIAL FERMENTATION

In our daily lives, we encounter all kinds of fermented products. Well-known food products are yogurt, cheese, cocoa beans, coffee beans, sour cream, pickles, sauerkraut, salami, bread, sourdough bread, wine, beer, vinegar. But bioethanol is also a product that is released during a fermentation process (alcohol fermentation). We also know many examples of fermentation products in the agricultural sector: silage of silage of silage maize or grass, biogas, composting, synthetic amino acids, certain organic acids (including lactic acid, acetic acid, citric acid), enzymes (including phytase), vitamins, antibiotics and vaccines.

Fermentation is a process that helps break down large organic molecules via the action of microorganisms into simpler ones (Sharma et al. 2020). Fermentation is a natural way of improving vitamins, essential amino acids, anti-nutrients, proteins, feed appearance, flavours and enhanced aroma. The type of fermentation depends on its byproducts. For example, lactic acid fermentation is a type of fermentation that produces lactic acid. Alcohol fermentation produces alcohol, such as ethanol, aside from CO_2. In this paper, the focus is on "lactic acid fermentation", because the multiplication of lactic acid bacteria, the consequent production of lactic acid and reduced pH, are all beneficial for improving gastrointestinal health.

In lactic fermentation, two types can be distinguished: 1) homofermentative form and 2) heterofermentative form (Figure 2). The main difference is that homofermentative strains produce 2 molecules of lactic acid from 1 glucose molecule, while the heterofermentative strains from 1 glucose molecule produce only 1 molecule of lactic acid and 1 molecule of acetic acid/ethanol. Depending on the purpose of the fermentation, hetero- and/or homofermentative strains can be chosen.



a) homofermentative b) heterofermentative

Figure 2 Lactic acid fermentation types (Kumar et al., 2015)

There are two methods of fermentation (Photo 1):

1) Submerged / liquid (free water is present; dry matter content 2 to 35%)
2) Solid-state (there is no free water available; dry matter content 45 to 65%).

Photo 1 Liquid fermentation (left) and solid-state fermentation (right)
(Photos by the author)

Microbes always need moisture: fermentation of raw materials with a dry matter greater than 70% is very difficult/slow. In addition to moisture, microbes also have requirements for temperature, pH value, and nutrients in the medium in/on which they grow. Most fermentations are anaerobic; however, some microbes prefer aerobic circumstances.

Each microbe (lactic acid bacteria, yeasts, fungi) has a growth curve (Figure 3) to be subdivided in 4 stages: lag phase, log phase, stationary phase and decline phase. For a successful fermentation, it is crucial to keep the lag phase as short as possible. Especially when we talk about "fermentation on farm". After all, there is the risk of microorganisms present in the air and on the raw materials to be fermented. Due to the addition of moisture and heat, there is a good chance that the microbes already present on the raw materials will grow, whereas the added starter culture (inoculant) is still in the lag phase.

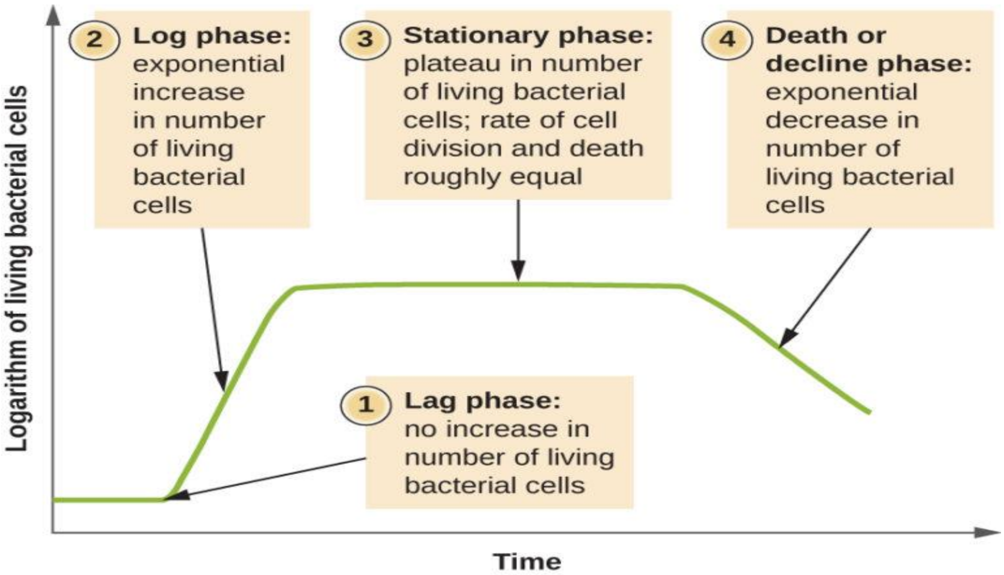


Figure 3 Growth curve of microbes can be divided into four different phases
(source: SUNY ER services, microbiology)

That is why it is important to ensure that the starter culture is already active (read: in the log phase) and thus immediately starts multiplying in the fermenter (Photo 2). A second important aspect is to ensure that the starting level of the starting culture is high enough to become the dominant microbe population. If there are already 200,000 colony-forming units of an undesirable lactic acid bacterium in the product, it is necessary to start with at least 400,000–500,000 colony-forming units of the desired starting culture (Scholten, personal communication).

Photo 2 Fermenters in laboratory versus fermenters in practice
(Photos by the author)

During the fermentation process, lactic acid bacteria grow and convert glucose into lactic acid and a small amount of acetic acid. As a result, pH value goes down. Typical values can be found in Table 1.

Table 1 Characteristics of fermented raw materials (Scholten, personal communication)

	RAW MATERIALS	
	DRY	FERMENTED[1]
Lactic acid bacteria (cfu/ml)	10^2 – 10^4	10^8 – 10^9
Lactic acid[2]	non detectable	5 – 7%
Acetic acid[2]	non detectable	0.5 – 0.7%
pH value	5.5 – 6.5	3.5 – 4.0

[1]fermented by lactic acid bacteria; [2]recalculated to 88% dry matter

FERMENTATION AND BREAKDOWN OF ANTI-NUTRITIONAL FACTORS

Microbial fermentation is a suitable technology to break down anti-nutritional factors; as proven by dozens of published scientific papers. A decisive factor for this unique property of fermentation lies in the process conditions: temperature, moisture and time and the presence of nutrients, and lactic acid bacteria. A liquid fermentation usually takes 24 hours, while a solid-state fermentation takes an average of 72 to 96 hours. During this fermentation time, feed particles are “soaked”, and this is the first important step initiating several bioconversion processes. Such as, for example, the activation of the endogenous enzymes *(e.g., phytase, protease)*. In addition, certain lactic acid bacteria can also produce enzymes themselves. Given the fact that lactic acid bacteria multiply by a factor of 1,000 to 10,000 during the fermentation time, there is a huge bioconversion potential.

The most common anti-nutritional factors are trypsin inhibitor, glucosinolates, tannins, stachyose, raffinose, phytate-phosphorus, and non-starch polysaccharides. In the following sections of this article, the focus is on the breakdown of anti-nutritional factors in the "golden standard" soybean meal. Many scientific papers are published in which clearly is proven that microbial fermentation substantially break down the most well-known ANF's in soybean meal: trypsin inhibitor, allergenic proteins glycinin and ß-conglycinin, and the undigestible sugars stachyose and raffinose (Chen et al., 2021; Chi & Cho, 2016; Liu et al., 2022; Yan et al., 2022; Zhu et al., 2017) (Table 2, 3 and 4). Several of this ANF's are heat-lable, which implicates they are not broken-down by the traditional toasting of soybean meal.

Table 2 Trypsin Inhibitor and pH analysis of soybean meal and fermented soybean meal (Chi & Cho, 2016)

In dry matter	SBM[1]	FSBM (fermented soybean meal) with			
		B.A.[2]	L.A.	L.P.	S.C.
pH	6.80[b]	7.56[a]	4.52[e]	4.72[d]	6.43[c]
TI (mg/g)[3]	4.77[a]	0.67[cd]	0.83[c]	0.53[d]	1.25[b]

Means in a column with different subscripts were significantly different ($p < 0.01$); Each value represents the mean of three replicates. [1]SBM = soybean meal, [2]B.A. = Bacillus amyloliquiefaciens, L.A. = Lactobacillus acidophilus, L.P. = L. plantarum, S.C. = Saccharomyces cerevisiae, [3]TI = trypsin inhibitor

Table 3 Lactic acid, pH and anti-nutritional factors in soybean meal and fermented soybean meal (Yan et al., 2022)

	SBM[1]	FSBM-A[2]	FSBM-B[3]
pH	6.33	4.95	4.76
Lactic acid (mg/g)	10.25	110.30	106.94
Glycinin (mg/g)	160.81	63.45	58.95
ß-conglycinin (mg/g)	144.87	60.38	56.34
Trypsin Inhibitor (mg/g)[3]	8.39	0.34	0.21

[1]SBM = soybean meal, [2]FSBM-A = fermented soybean meal, SSF, 30–40C, 3-days, drying stage 180C for 20 minutes, [3] FSBM-B = fermented soybean meal, 2-stage fermentation: 1) liquid, 15–30C, 72 h, followed by 2) SSF, 30–37C, 3-days, drying stage 50–60C for 48–72 hours

Chen et al. (2010) published a study on various types of soy products (Table 5). In conclusion, one can say that the two-stage fermentation (first with Aspergillus, then with Lactobacillus) results in highest tricholoroacetic acid soluble protein, highest in vitro protein digestibility, highest lactic acid content and consequently lowest pH, and undetectable levels of stachyose and raffinose.

Table 4 Lactic acid, pH and anti-nutritional factors in soybean meal and fermented soybean meal (Zhu et al., 2017)

	SBM[1]	FSBM[2]
TCA soluble protein (%)	1.21[b]	12.1[a]
Glycinin (mg/g)	150.2[a]	27.0[b]
ß-conglycinin (mg/g)	123.2[a]	36.1[b]
Trypsin Inhibitor (mg/g)[3]	11.2[a]	0.3[b]
Stachyose (%)	5.8[a]	0[b]
Raffinose (%)	1.8[a]	0[b]

[a,b] means within a row with different superscripts are significantly different ($p < 0.05$), [1]SBM = soybean meal, [2]FSBM = fermented soybean meal

Table 5 Characteristics of different soybean products (Chen et al., 2010)

	SBM[1]	$FSBM_{A}$	$FSBM_{A+L}$	SPC
Crude Protein (%)	43.09[2c]	47.78[b]	47.50[b]	61.87[a]
TCA soluble protein (µmol/g)	65.26[c]	110.33[b]	1,010.32[a]	70.26[c]
In vitro protein digestibility (%)	87.5[b]	85.89[b]	92.23[a]	87.63[b]
pH	6.98[a]	6.33[b]	4.50[c]	6.75[a]
Lactic acid (µmol/g)	0[c]	3.69[b]	140.25[a]	0[c]
Stachyose (%)	6.39[a]	0.42[c]	ND[3d]	1.93[b]
Raffinose (%)	1.35[a]	0.24[c]	ND[3d]	0.42[b]

[1] SBM = soybean meal; $FSBM_{A}$ = fermented soybean meal with Aspergillus; $FSBM_{A+L}$ = fermented soybean meal with Aspergillus + Lactobacillus; SPC = soy protein concentrate., [2]Values are the mean of four replicates, [3]ND = non-detectable. [a,b,c,d] Means in the same row without the same superscripts are significantly different ($p < 0.05$)

Wang et al. (2020) published a study on fermentation of soybean meal. The pH value and β-conglycinin and glycinin concentrations in FSBM were lower than in SBM. The fermentation process changed peptide size distribution of SBM. The percentage of large peptides (60kDa and higher) and middle peptides (20 to 60kDa) were lower in FSBM than in SBM, while the percentage of small peptides (20 kDa and lower) was higher (Table 6). In general, it can be said that reducing the peptide size will have a positive effect on the digestibility of protein, especially for young animals.

Table 6 Chemical composition of soybean meal (SBM) and fermented soybean meal (FSBM) (as-fed basis; Wang et al., 2020).

	SBM	FSBM
pH	6.5	4.9
Glycinin (mg/g)	89.7	38.7
ß-conglycinin (mg/g)	72.8	42.3
Peptide size distribution (%)		
60 kDa and higher	25.3	8.9
20 to 60 kDa	49.4	45.1
20 kDa and lower	25.3	46.0

SBM = soybean meal; FSBM = fermented soybean meal

DEVELOPMENT IN ANIMAL PERFORMANCE IN RECENT DECADES

Due to better nutrition, better genetics, better husbandry conditions, and better management skills, there has been a huge increase in animal performance in recent decades (Figure 4). However, this leads to the fact that more and more is asked of the animals, while on the other hand more and more preventive measures (including antibiotics, zinc oxide, coccidiostats) are prohibited / limited by law. This requires a huge effort to come up with a holistic approach to further improve animal health, welfare, and performance.

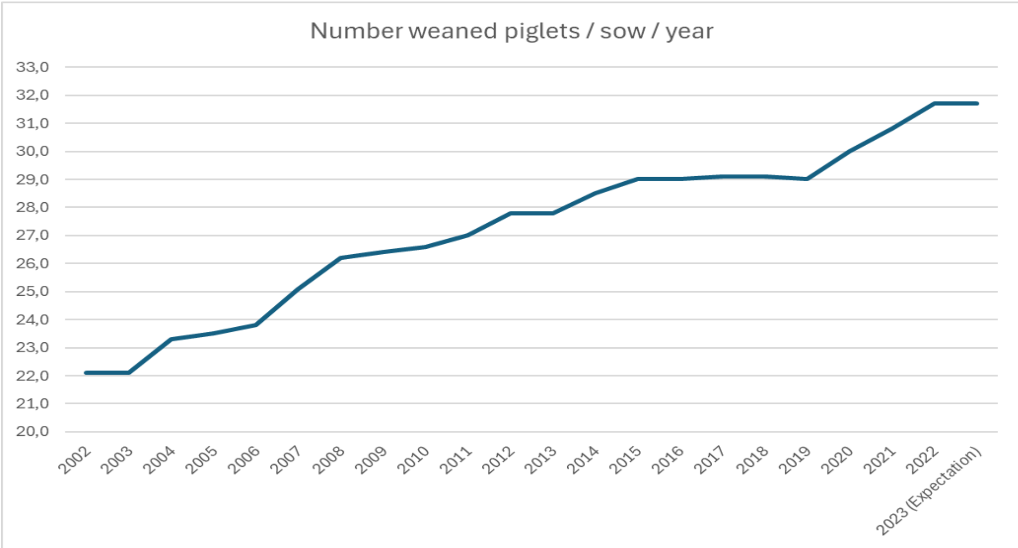


Figure 4 Development of the number of weaned piglets per sow per year in the Netherlands (Agrimatie, 2023)

FERMENTATION AND GASTROINTESTINAL HEALTH

In various countries (e.g. the Netherlands, Denmark) action programmes are being implemented to significantly reduce the use of antibiotics. Up to now in Dutch pig farming, the use of antibiotics has decreased by about 75% compared to 2009. However, especially in young animals, gastrointestinal disorders are an important cause of antibiotic use.

It is generally accepted that:

- gastrointestinal health is a key factor for a healthy animal with good production and is the basis for animal welfare;
- Microbiota play an important role in maintaining gastrointestinal health;
- Villus height (VH) to Crypt depth (CD) ratio is an important parameter for the absorptive capacity of the small intestine in both pigs and poultry;
- Higher VH:CD ratio means higher absorption of nutrients.

After weaning, villus shortening and crypt deepening in the small intestine of piglets often occur within a few days. Sufficient feed intake directly after weaning seems to prevent undesirable changes of the morphology in the small intestine. Diet formulation might influence gastrointestinal morphology, physiology, and microbiology. Scholten et al. (2002) studied the effects of adding fermented wheat (0 versus 45%) to liquid diets on gastrointestinal characteristics in weaned piglets. The result of that study indicates that feeding a partly fermented liquid diet to weaning piglets may be a concept to prevent undesirable changes in mucosal architecture after weaning (Table 7).

Table 7 Morphological characteristics in first segment small intestine of weaned piglets fed a liquid diet with 0% (FERM-0) or 45% (FERM-45) fermented wheat (Scholten et al., 2002).

	FERM-0[1]	FERM-45
Villus height (μm)	287[a]	360[b]
Crypt depth (μm)	255	242
VH : CD ratio	1.1[a]	1.5[b]

[a,b] means with different superscripts are significantly different ($p < 0.05$), [1] FERM-0: 45% non-fermented wheat, FERM-45: 45% fermented wheat

Wang et al. (2007) studied the effect of lactic acid fermented soybean meal (FSBM) on growth performance, intestinal microflora and morphology of weaned piglets (Figure 5 and 6). The addition of 10% FSBM in the diets of piglets improved ($p < 0.05$) the growth performance (data not shown), increased ($p < 0.05$) the numbers of intestinal lactobacilli, decreased ($p < 0.05$) the numbers of intestinal enterobacteria and increased ($p < 0.05$) the villus height (not shown) and villus height to crypt depth ratio at the small intestine mucosa compared to the control group.

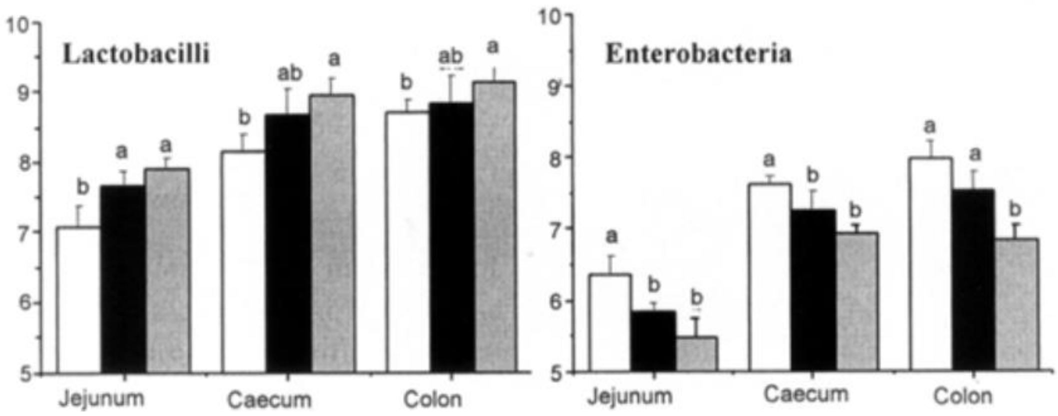


Figure 5 Effect of diet (white: control; black: 5% FSBM; grey: 10% FSBM) on the numbers of lactobacilli and enterobacteria (log cfu/g) in the content from jejunum, caecum and colon of piglets (n = 12) (Wang et al., 2007)

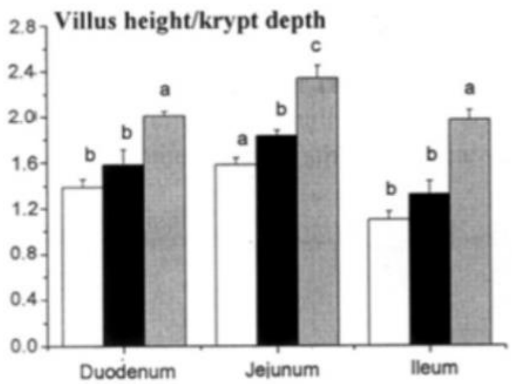


Figure 6 Effect of diet (white: control; black: 5% FSBM; grey: 10% FSBM) on the morphology of the villus height/crypt depth at different sites of small intestine (Wang et al., 2007)

Liu et al. (2022) conducted a weaned piglet trial in which they looked at the effect of replacing 12% soybean meal with soy protein concentrate (8.08%), fish meal (8.32%), or fermented soybean meal (9.74%). As shown in Table 8., the average daily gain (ADG)of piglets fed FSBM was significantly higher than those fed the other three treatments, and the gain feed ratio (G/F) ratio of piglets fed FSBM was higher than the CON and SPC groups. Also, piglets fed FSBM had the highest apparent total tract digestibility of gross energy and crude protein compared with the other three treatments. Piglets fed FSBM had significantly greater villus height, lower crypt depth and greater ratio villus height/crypt depth (Table 8).

The effect of feeding dry feed (DF), non-fermented liquid feed (NFLF), and fermented liquid feed (FLF) to growing pigs on aspects of gastrointestinal ecology was investigated by Canibe & Jensen (2003). Five pigs from each diet were sacrificed at an average body weight of 112 kg and digesta from the gastrointestinal tract (GI-tract) was obtained to ex amine variables describing some aspects of the gastrointestinal ecology. Fermented liquid feed contained high levels of lactic acid bacteria (9.4 log cfu/g) and lactic acid (approximately 169 mmol/kg), and low levels of enterobacteria ($P < 0.001$ for feed intake). The results from the present study indicate that feeding FLF may be a valid feeding strategy to decrease the levels of enterobacteria and increase the levels of lactic acid bacteria in the GI-tract of growing pigs (Table 9).

FERMENTATION AND GROWTH PERFORMANCE

Muniyappan et al. (2023) investigated the effects of soybean meal fermented by Enterococcus faecium as a replacement for soybean meal on growth performance and apparent total tract digestibility of weaned pigs. The four diets (SBM, 3, 6 and 9% FSBM) were formulated using fermented soybean meal to replace 0, 3, 6 and 9% of soybean meal, respectively. The trial lasted for 42 days. As can be seen from Figures 7 and 8, supplemental FSBM increased ($P < 0.05$) the body weight (BW) of piglets at days 7, 21 and 42 and ADG at days 1–7, 8–21, 22–42 and 1–42, and average daily feed intake (ADFI) at days 8–21, 22–42 and 1–42 and G/F at days 1–7, 8–21 and 1–42, and crude protein, dry matter, and gross energy digestibility at day 42, and lowered ($P < 0.05$) diarrhoea at days 1–21 and 22–42 (data not shown). Overall, using fermented soybean meal of piglets improves the health and performance of piglets.

Table 8 Effect of diets supplied with soy protein concentrate, fish meal, or fermented soybean meal on growth performance, diarrhoea rate, apparent total tract digestibility, intestinal morphology of weaned piglets (Liu et al., 2022)

	CON[1]	SPC	FM	FSBM
Initial body weight (kg)	6.74	6.73	6.74	6.72
Day 0–14				
ADG (g)[2]	277[c]	302[bc]	334[ab]	346[a]
ADFI (g)[3]	457	477	504	504
G/F[4]	0.61[b]	0.63[b]	0.68[a]	0.69[a]
Diarrhoea rate (%)	5.95[a]	2.86[b]	4.29[ab]	2.14[b]
Day 0–14				
ATTD GE[5]	77.17[c]	79.36[b]	79.71[b]	81.04[a]
ATTD CP[5]	72.20[c]	75.49[b]	74.79[b]	77.79[a]
Villus height (µm)[6]	445.51[b]	490.54[ab]	496.21[ab]	515.03[a]
Crypt Depth (µm)	372.96[a]	344.05[b]	347.81[b]	339.06[b]
VH/CD ratio	1.20[b]	1.44[a]	1.43[a]	1.53[a]

[1]CON = basal diet with soybean meal, SPC = basal diet with 12% SBM replaced by soy protein concentrate, FM = basal diet with 12% SBM replaced by fish meal, FSBM = basal diet with 12% SBM replaced by fermented soybean meal. [2]ADG = average daily gain. [3]ADFI = average daily feed intake. [4]G/F = growth to feed ratio. [5]ATTD apparent total tract digestibility, GE = gross energy, CP = crude protein. [6]Measured at day 28, 4 piglets per treatment, values are from the duodenum section small intestine. [a,b,c] Mean values within a row with different letters differ at $p < 0.05$

Table 9 Microbial counts (log cfu/g) along the gastrointestinal tract of pigs fed the experimental diets (Canibe & Jensen, 2003)

Bacterial counts in GIT (log cfu/g)	Dry Feed	Liquid Feed (non-fermented)	Liquid Feed (fermented)
Lactic Acid Bacteria			
Stomach	< 5.4[a]	7.9[b]	9.0[c]
Distal small intestine	< 6.3[a]	< 6.5[a]	7.2[b]
Enterobacteria			
Stomach	3.8[a]	5.7[b]	< 3.2[c]
Distal small intestine	5.5[a]	6.6[b]	< 4.1[c]

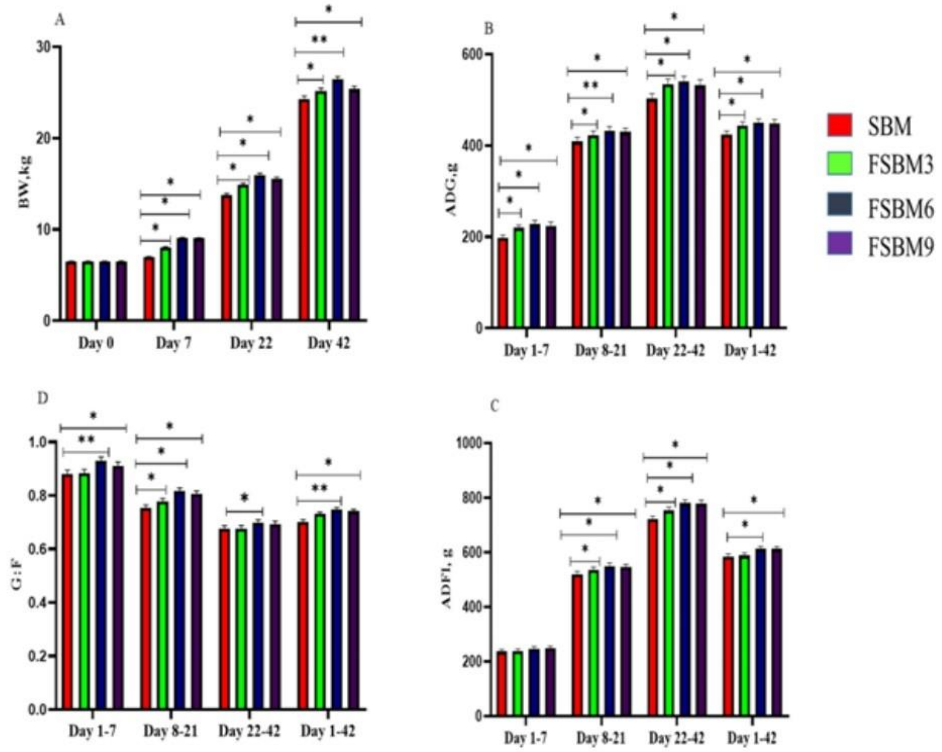


Figure 7 Effect of fermented soybean meal (FSBM) on growth performance in piglets. A) Body weight (BW), B) Average Daily Gain (ADG), C) Average Daily Feed Intake (AFDI), D) Gain to Feed ratio (G:F). * P < 0.05 ** P < 0.001 (Muniyappan et al., 2023)

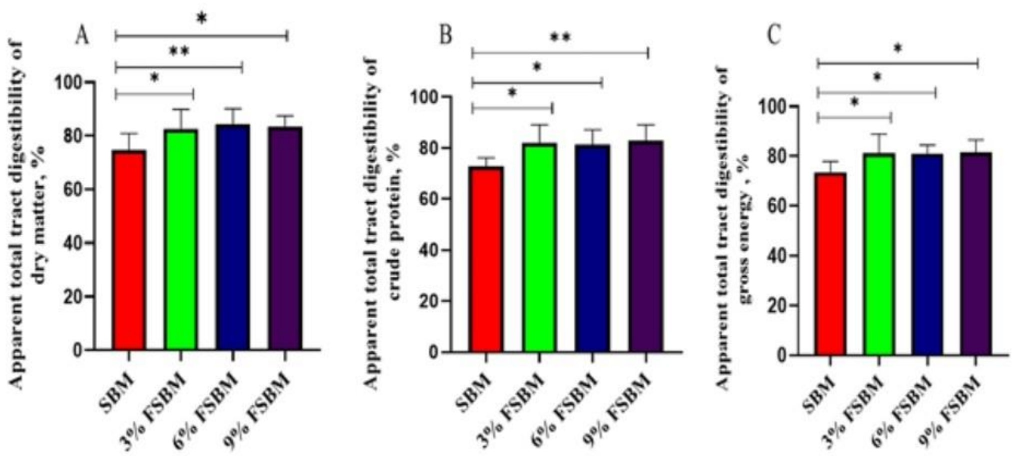


Figure 8 Effect of fermented soybean meal (FSBM) on apparent total tract digestibility in piglets. A) Dry Matter (DM), B) Crude Protein (CP), C) Gross Energy (GE). * P < 0.05 ** P < 0.001 (Muniyappan et al., 2023)

Fan et al. (2022) evaluated the effects of dry feed and liquid feed including fermented mixture on growth performance and nutrient digestibility in weaning pigs. The three dietary treatments (all non-pelleted diets) were: 1) a standard dry feed as the control (CON), 2) a control diet supplemented with antibiotics (AB), and 3) a liquid feeding with a fermented diet (LFD). The liquid feeding diet, having the same composition and proportion of each ingredient as the control diet, was prepared by storing the dietary cereals (corn, soybeans, etc.) and water (1:0.5, wt/wt) in a closed tank at 26–30 °C with enzymes and bacteria, and then adding the remaining dietary ingredients immediately before feeding. The whole trial lasted 42 days. The results showed liquid feeding group significantly increased ($p < 0.05$) average daily gain, average daily feed intake, and final body weight compared to the other two dietary groups (Table 10). The digestibility of crude protein, ether extract, ash, gross energy, Ca, and P also improved in the liquid feeding group (data not shown). In addition, microbiota measurement suggested an increase in *Lactobacillus* content and a decrease in *Escherichia coli* in the caecal and colonic digesta of piglets in the liquid feeding group (data not shown). In conclusion, the combination of liquid feeding + fermented feedstuffs seem to be a good alternative for the use of antibiotics, as shown by higher feed efficiency and better growth performance in the piglets.

Table 10 Effects of liquid feeding of fermented diet on growth performance and diarrhoea of weaned piglets (Fan et al., 2022)

	CON	CON + AB	LFD
Number of piglets	66	66	66
Days 1-14			
ADG (g)[3]	117.4^{b}	152.9^{a}	166.5^{a}
ADFI (g)[3]	252.5^{b}	276.5^{ab}	302.9^{a}
F/G[3]	2.22^{a}	1.83^{b}	1.84^{b}
Diarrhoea rate (%)	11.0	8.8	9.6
Days 1-42			
ADG (g)[3]	341.1^{b}	369.6^{b}	454.1^{a}
ADFI (g)[3]	539.9^{b}	589.1^{b}	685.6^{a}
F/G[3]	1.59	1.59	1.51
Diarrhoea rate (%)	9.7	6.8	6.8

^{a,b} means in a row with different superscripts are significantly different ($p < 0.05$); CON = standard dry feed; CON + AB = control + antibiotics; LFD = liquid feeding with fermented feedstuffs; [3]ADG: average daily gain, ADFI = average daily feed intake, F/G = feed to gain ratio

CONCLUSIONS

Microbial fermentation is a technology with enormous potential to provide a solution to today's challenges in animal protein production. Fermentation of raw materials reduces the use of antibiotics and is a good alternative to other additives *(e.g. zinc oxide)*. Fermentation breaks down anti-nutritional factors in raw materials, without the need to use high-energy demanding techniques such as extruders or expanders. In addition, the heat-stable ANFs are also largely phased out by fermentation. Degradation of ANFs improves feed efficiency and makes it possible to better value certain (protein-rich) raw materials in feeds for monogastric animals. Finally, fermentation also contributes to reducing the carbon footprint. On the one hand, because of the better feed efficiency, but on the other hand also because of the upgrading of raw materials that are normally not or minimally included in rations for monogastric animals. Think of fibre-rich raw materials.

REMARKS

Given the limited space in this article, there are only studies on the effect of fermented soybean meal in pigs listed. However, dozens of articles have appeared in the literature with other fermented raw materials (e.g. rapeseed meal, sunflower meal, cereals, peas, cottonseed meal, wheat semolina, soya hulls), as well as with other animal species (broilers, laying hens, calves, shrimps, aqua).

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