Indigenous Microorganisms as an alternative Odour-reduction approach in Pig Production systems: A review

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ABSTRACT

Odour emissions from pig production facilities are the most significant limitations to pig production. Effective interventions to control odour such as dietary modification, liquid-solid separation, bio-filtration, covers for manure storage, and dust suppression have been made. However, these measures are costly and unaffordable by most pig farmers. The use of Indigenous micro-organisms (IMOs) has been suggested as a less costly alternative approach to control odour. The IMOs can be used to manage odour in a natural and environmentally beneficial way. They aid in the breakdown of organic materials and lessen the offensive smell by introducing helpful bacteria to the farm. The micro-organisms help to break down faecal material rapidly to a fertilizer rich material, while ensuring that there are no smells or flies. This enables rearing of pigs close to the living quarters in areas where land is scarce and heavily populated, hence encouraging more farmers to adopt the enterprise. This review focuses on the use of IMOs as a less costly approach to control odour in pig production systems.

Keywords: Ammonia emissions, IMO, Odour emission, Pork

1.0 INTRODUCTION

Livestock is a pivotal sector in the growth of global agriculture, especially in developing countries, where meat consumption has been growing at 5-6% per annum (FAOSTAT, 2024). Global meat production as of 2024 stands at 351 million metric tons of which pork contributes 30.5% (Statista, 2024). The contribution of pig meat to the total global livestock meat is relatively higher than the 21% of beef and veal, and the 5% of sheep (Statista, 2024). The popularity of pork is driven by its flavor, versatility in cooking and cultural significance in many regions of the world (Borrisser-Pairó *et al*., 2016; Chernukha *et al*., 2023; Vicente and Pereira, 2024). Pork contains high-quality protein, B-complex vitamins, and essential minerals such as zinc and iron (PORTFIR, 2021).

The global pork consumption per capita, carcass weight equivalent, has increased from 9.1 kg in 1964/66 and is projected to be 15.1 kg by 2030 (FAOSTAT, 2024). In developing countries, pork consumption per capita, carcass weight equivalent, is projected to be 12.2 kg by 2030 which is almost four-fold the consumption in 1964/66 (FAOSTAT, 2024). Despite pork popularity, offensive odour emissions from pig facilities remain a significant limitation to global pig production (Lemay, 1999; Hansen et al., 2016; AfrII, 2016; Choi et al., 2024). The odour from pig waste doubles as serious nuisance for people living near pig farms and an environmental pollutant (Aarnink and Verstegen, 2007). Exposure to highly odorous gases affects the health and the performance of both animals and workers, and results into resentment of pig farming by farmers (Urabain et al., 1994; Amy et al., 1998; Bibbiani and Russo, 2012). Exposure to some odorous emissions from pig stys causes nausea, coughing, headaches, dizziness, nasal complaints, eye irritation, severe pulmonary illnesses, impairment of lung function and premature death (Simonton and Spears, 2007). In some countries, odorous emissions from pig stys have been associated with conflicts among communities, especially those who do not keep pigs (Phiri et al., 2003).

Odour comes from a mixture of various compounds present in pig manure. These include sulphurous, indolic and phenolic compounds; volatile fatty acids; ammonia; methane; hydrogen sulphide; volatile amines; mercaptans; esters; carbonyls; aldehydes and alcohols (Zahn et al., 2000; Marta et al., 2018; Choi et al., 2024; Song, 2024). Odour mainly arises from microbial conversion of protein and fermentable carbohydrates in the large intestine of pigs and by microbial conversion of urinary and faecal compounds in the manure as well as spilled feed (Amy et al., 1998; Chastain, 2003; Le et al., 2005a). Reduced sulphur-containing amino acids are among the most odorous compounds, formed by anaerobic decomposition of sulphur-containing amino acids, methionine, cysteine and reduction of sulphate or sulphonates such as taurine (Pond et al., 1995; Van Soest, 1994; McDonald et al., 1987). There is evidence that sulphate, which is in form of sodium sulphate, can be used by micro-organisms more efficiently than elemental sulphur (McDonald et al., 1987). In the liver, sulphide that occurs as hydrogen sulphide is converted to sulphate, the end product of catabolized sulphur-containing amino acids, and is finally secreted in urine and saliva (Van Soest, 1994). Most forms of sulphur can be used by bacteria because sulphate is reduced through sulphate (Van Soest, 1994). Hydrogen sulphide is one of the several noxious gases emitted and contributes significantly to odour, even at very low concentrations, with odour threshold ranging from 0.005 to 0.3 ppm (Kim, 2014).

It is important to note that the strength and offensiveness of the odour generated depends on the quantity and composition of the feed being digested, (Amy et al., 1998; Choi et al., 2024). Nonetheless, there exists minimal information on the feed-related initiatives that have been employed to reduce odor at the feeding level. The current review, therefore, seeks to consolidate the different studies on odour management, especially using indigenous microorganisms (IMO). The review first examines studies on the role of diet in odour emission, and then explores the use of indigenous micro-organisms as an environment-friendly and low-cost initiative which has proven effective in odour management, not only in pigs in other livestock.

1.1 Diet alteration and its contribution to odour emission reduction in pig houses

Among finishing pigs, the level of odor and ammonia emissions was seen to increase with the crude protein (CP) in the diet (Hayes et al.,2024). Beyond 19% CP, the odour emission was, however, seen to reduce. The ammonia emission rates at 13%, 16%, 19% and 22% CP, for example, were 3.11, 3.89, 5.89 and 8.27 g/day/ animal. In a related, study lowering CP for finishing pigs from 15% to 12% did not reduce the odour emissions but significantly lowered the ammonia emissions from pig manure (Le et al., 2009). Studies have showed that feeding pigs on low protein diets could reduce ammonia emissions (Ball et al., 2022; Yu et al., 2019; Wang et al., 2018; Hansen et al., 2014; Otto et al., 2003). To close the amino acid deficiency gap (particularly lysine which is limiting in CSBM diets), supplementation with exogenous critical amino acid sources could suffice without increasing ammonia emissions (Wang et al., 2018; Sutton et al., 1999). In a study by Le et al. (2008), it was reported that the CP or FC level did not affect odour emissions but their interaction did. With higher dietary CP, increasing FC reduced odour emissions from pig manure and, at lower CP level, increasing FC increasing odour emissions. Similarly, Nahm (2003) also realised reduced ammonia emission and N excretion when FC were added into pig diets. As with earlier studies, the study by Le et al. (2008) also reported high ammonia levels at high CP levels which would be counteracted by increasing the FC levels in the diet. Thus, in a comprehensive review of dietary effects on odour emissions from pig manure, Le et al. (2005b) recommended that not only the concentration of the CP but also the balance between these and fermentable carbohydrates (FC) are crucial in reducing odour emissions from pig houses.

1.2 Earlier initiatives to control of odour in pig production systems

Efforts to control dour emissions in pig production systems have been made. Most of the efforts have focused on odour source like buildings and facilities, manure storage covers, land application sites, diet manipulation, bio-filter, bio-scrubbers, mechanical aeration, liquid-solid segregation, and dust suppression (Bundy et al., 1997; Amy et al., 1998; Baskota et al., 2021).

For instance, covering the pig manure with organic material such as wheat straw and corn stalks has been shown to significantly reduce odour from manure storage facilities (Bundy et al., 1997). Other covers include organic materials like corn stalks/cobs, straw, rice hulls, peat moss; inorganic material like leka rock and oil layer; solid roofs, and inflatable covers (Lemay, 1999). Lowering dietary crude protein levels as discussed above, and supplementing with essential amino acids has also proven a potential option (Aarnink *et al*., 2007). A continuous pit recirculation system with air-treated liquid manure effectively reduces ammonia, hydrogen sulfide, nitrogen compounds, and odorous volatile organic compounds emission from pig houses (Choi *et al*., 2024).

Although all these interventions are effective, they are expensive and unaffordable by most pig farmers, particularly in developing countries. There is an urgent need to search for low-cost alternative technologies that are able to completely decompose pig manure, hence controlling odour from pig production facilities. This will enable small and marginal farmers to rear pigs. Among these alternatives the use of IMOs has proven outstanding. The IMO have been credited for managing odorous emissions from pig production facilities (Amy et al., 1998; Ndyomugyenyi and Kyasimire, 2015; Mamawi *et al*., 2020). Therefore, this review details the initiatives to employ IMO in controlling odour in pig production systems.

2.0 METHODOLOGY

Although several studies have been conducted on odour-reduction in pig houses, few have concentrated on the use of IMO. Due to this literature dearth, we did not limit our search to a given time range. However, the literature retrieved from the different databases shows that intense initiatives towards odour reduction started in the mid to late 1990s. The literature reviewed in this paper was accessed from Google scholar and the Google search engine. From our search, a total of 49 publications were reviewed, 27 of which were peer-reviewed journal articles and the 22 were non-journal articles.

2.1 Indigenous microorganisms

The IMOs are naturally occurring microbes that have adapted to the environmental conditions where they live and are capable of accelerating decomposition of organic materials (Cheimela *et al*., 2013). They are able to decompose and convert complex organic materials into simple compounds (Batten, 2015). The IMOs such as bacteria and protozoans are unicellular, fungi may be unicellular or multicellular, while algae may exist in all the three forms (Stuart, 2005). One of the major beneficial IMOs used in natural farming is Lacto bacilli (Gil, 2003). This particular strain of beneficial IMOs is popularly used in composting, and specifically help to arrest odour associated with anaerobic decomposition (Gil, 2003). Lactic acid bacteria thrive and feed on the ammonia released during the decomposition of organic matter and its application in organic farming is enormous, particularly natural pig farming (Gil, 2003). In this case, pigs are kept on floor made of compost, soil and other organic matter such as saw dust on which lactic acid bacteria serum are sprayed (Gil, 2003). There is no need to clean up the pens of excretions and urine because lactic acid bacteria convert these wastes into harmless organic matter through decomposition (Gil, 2003).

Yeast such as Saccharomyces cerevisiae, Candida utilis can degrade organic compounds to carbon dioxide and water with the use of free molecular oxygen or sugars to ethanol in the absence of free molecular oxygen (Mandalaywala et al., 2017). Photosynthetic bacteria for example Rhodopseudomonaspalustris and Rhodobactersphaeroide degrade difficult biodegradable compounds like sludge (Mandalaywala et al., 2017). Actinomyces for example Streptomyces albus, Streptomyces griseus with sufficient hydraulic retention time degrade organic phosphorus compounds and orthophosphate is released from phosphorus containing compounds (Mandalaywala et al., 2017). Fungi like Aspergillus oryzae and Mucorhiemalis decompose organic matter rapidly to produce alcohol, esters and antimicrobial substances and these suppress odours of waste water (Mandalaywala et al., 2017). Table 1 shows that microorganism species from IMO solution are gram positive and facultative anaerobes, while aerobic microorganisms are moulds and yeast (Mamawi et al 2020).

2.2 Collection of indigenous microorganisms from the environment

The IMOs are obtained from local forest under healthy old robust trees with characteristic deep humus and litter because such areas have high soil fertility and microbial biodiversity (Gil, 2003). Bamboo attracts powerful beneficial IMOs because the roots exude sugary materials that attract the microorganisms (Gil, 2003). Several methods have been employed to collect the IMOs, especially from within the farming or forest environment. A wooden box of length, 30 cm x width, 20 cm x height, 10 cm and thickness, 1.2 cm is used (Han-Kyu (2011). The wooden box is filled with 1 kg of steamed rice (Figure 1). The wooden box is covered with white plain paper, which is fastened to the box by the rubber band. An area 30cm x 20cm is marked in the soil and excavated 8 cm deep. The rice-filled wooden box is placed in this pit in an isolated area, covered with leaves for natural inoculation by water and air-borne microbes (Farishya, 2018). The box is removed from the soil on the 5th day to check whether the rice is covered with IMOs. If the rice has IMOs, it is put in sterile bucket, covered with aerated tissue paper, and kept at room temperature prior to multiplication of the organisms.

A wooden box or split bamboo internode, filled up to 7 cm long with steamed rice is used to collect IMOs from the forest (ECHO Staff, 2011). The rice is not compacted to accommodate both anaerobic and aerobic microorganisms. The box is covered with porous paper to allow air to move in and out, tied snugly with string or a rubber band. The covered box is placed into a shallow hole located in the soil of an area where forest leaves are falling and decomposing. The weight of the leaves accumulating on top of the covered box is not allowed to press the paper down to touch the rice surface. During the rainy season, the box is protected by covering the layer of fallen leaves with a plastic sheet. The box is removed from the soil after two days in hotter conditions or ten days in colder conditions. When collecting IMOs from the forest, results are better when there is adequate soil moisture. When rice is retrieved from the forest, it should have a white mold (IMOs) growing on it.

Table 1: Microorganisms isolated from IMO solution (Mamawi *et al*., 2020)

Microbes	Identification	Characteristics	Description
Bacteria	Enterobacteriaceae	- Grain stain - Microscopic appearance - Oxygen relationship - Oxidase test - Spores	- Gram Negative - Rods - Facultative anaerobic - Negative - Non-spore forming
	Lactobacillus species	- Grain stain - Microscopic appearance - Oxygen relationship - Oxidase test - Spores	- Gram – positive - Rods in palisades - Anaerobic bacteria - Negative - Non – spore forming
	Bacillus species	- Grain stain - Microscopic appearance - Oxygen relationship - Oxidase test - Spores	- Gram – Positive - Rods in chain - Facultative anaerobic - Negative - Spore forming
	Staphylococcus	- Grain stain - Microscopic appearance - Oxygen relationship - Oxidase test - Spores	- Gram – Positive - Cocci in grape-like clusters - Facultative anaerobic - Positive - Non-spore forming
Yeast and Moulds	Aspergillus niger	- Stipes color - Surface - Vesicle serration - Metula covering - Shape	- Slightly brown - Smooth walled - Biseriate large size - Entirely - Glubose
	Aspergillus flavus	- Stipes color - Surface - Vesicle serration - Metula covering - Shape	- Pale brown roughened - Spherical - Biseriate - ½ to ¾ - Glubose ellipsoid

Raw rice (2.5 kg) is half cooked and placed in a wooden box of 12″ × 12″ × 4″ cubic inches (Seema et al., 2020). The 2/3 parts of the box is filled with the half cooked rice, while the remaining part (1/3) of the box is kept empty to enable the aerobic environment to the microbes. The box is covered with a sheet of white tissue/paper, wire mesh and thin plastic sheet, respectively to protect the rice from rodents or stray animals. The box containing the half-cooked rice is buried 5 cm deep in the soil under the trees for 7 days. The IMOs are successfully collected when the rice is covered with a white, cloudy microbes, with little or no presence of red and blue molds (Figure 2). The harvested rice-IMOs (0.5 kg) is mixed with 0.5 kg of brown sugar in the ratio of 1: 1. The rice-IMO-brown sugar mixture is placed in a cool environment for 7 days prior to multiplication. If the rice is covered with a green layer, the contents should be discarded and the process repeated (Han-kyu, 2010).

The IMOs are produced by cooking 2 kg of rice or any other carbohydrate source (Ndyomugyenyi and Kyasimire, 2025). After cooling, the rice is mixed with 0.25 kg of rock or common/table salt. The rice balls are made and each ball is rapped with a net or cloth. All the rice balls are joined together by tying with a string (Figure 2). The tied set of rice balls is buried 10 cm below the ground preferably under the trees. Manure, free from insect is an ideal environment for the balls. The rice balls are left underground for 5 days, removed and the net or cloth cover opened to expose the balls. The rice balls are smeared with 1kg of sugar, covered until brown liquid is observed (3-4 days), an indication of the presence of IMOs.

Figure 1: White coloured IMOs after 7 days

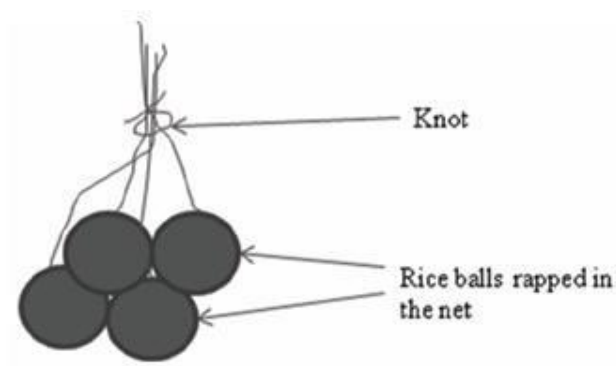

Figure 2: Rice rolls tied together with a strong (Ndyomugyenyi and Kyasimire, 2015)

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2.3 Growth and multiplication of IMOs

The growth of IMOs is longer in a natural environment than the lag phase normally observed in a batch culture or under ideal laboratory conditions (Stuart, 2005; Ananthanarayan and Paniker, 2006). This is due to limited nutrient availability and suboptimal environmental conditions in the environment such as temperature and moisture that cause stress (Stuart, 2005). Generally, IMOs grow over a wide range of temperatures, ranging from around freezing to above boiling point (Stuart, 2005). However, the optimum growth of IMOs is in the range of 25ºC to 40ºC (Afika et al., 2017; Mamawi et al., 2020), while the rate of degradation of organic matter is optimal at 25°C to 40°C (Afika et al., 2017). In addition to temperature, nutrients or substrates especially the fermentable sugars from the environment play a significant role in the growth of IMOs (Graeme and Graham, 2016). It has been shown that the presence substrates rich in growth promoting substances such as carbohydrates increases the growth of IMOs (Lakoma, 2018; Graeme and Graham, 2016; Hogg, 2005). Molasses and maize bran are commonly used substrates to grow IMOs. Molasses have a total sugar content of 25% comprising of sugars, fructose and dextrose, while maize bran has only 2.8% total (Lakoma, 2018).

To multiply IMOs, the harvested material, including the boiled rice is mixed with molasses at the ratio of 1:1 and fermented in clay crocks (earthenware pot) for at least one month (ECHO Staff, 2011). The resulting fermented IMO material is used to make various IMO solutions and products using water at the rate of 0.1 - 0.2%. The balls with trapped IMO are collected, mashed on to a clean polythene sheet (Ndyomugyenyi and Kyasimire, 2015). The smashed balls are thoroughly mixed with sugar (1 kg) and maize bran (1 kg) to allow for further multiplication of the microbes since two ingredients are nutrient sources (carbohydrates). The mixture is then placed in a tank/drum where water is added, while stirring so as to form a solution. The solution is stirred daily in the morning and evening for 5 - 7 days before application to the deep litter beds. After 5 - 7 days, sweet smell should be realized and product is ready for use.

2.4 Application of IMOs on deep litter pig houses

An ideal deep litter floor is made by laying of the bedding materials in layers in a one-metre deep hole from the bare soil ground (Mamawi et al., 2020). The size of the hole depends on the flock size. The first layer is charcoal, followed by sizable tree shoots, maize stalks, dry red soil mixed with lime and finally the litter. However, the litter bedding can as well be placed on top of concreted floors. Litter bedding can be any soft, dry organic material like wood shaving, rice husks and coffee husks, capable of absorbing moisture, and is not dusty or poisonous to the pigs. The solution is applied on deep litter floor every day in the morning and the litter is lightly turned for the faecal material to be mixed together with the litter (Ndyomugyenyi and Kyasimire, 2015). When 90% of the IMO solution is used up, 1kg of maize bran and 0.5kg of sugar are added to the remaining solution. The tank/drum filled with clean water and the mixture is ready to be used again. Measurements of maize bran and sugar can be adjusted depending on the quantity of IMO to be made.

2.5 Indigenous microorganisms and odour reduction in deep litter pig houses

The ability to detect smell from deep litter pig houses depends on the distance from the pig house, environmental conditions, and whether the floor is treated with IMO solution or not. In IMO treated deep litter floor, odour is not detected in the house throughout the day at various temperatures, pH and humidity, while in untreated floor, odour intensity is high in the morning at lower temperature of 23ºC and high humidity of 62% (Mamawi et al., 2020). In respect to the distance from the house, at a distance of 0, 10, 20, 30 and 40 meters, foul odour showed a significant difference between IMO treated and untreated deep litter floor with higher odour being high in untreated deep litter floor compared to IMO treated deep litter floor (Mamawi et al., 2020). Reduction of odour in the IMO treated floors could be due to aerobic decomposition of pig manure by the microorganisms in the IMO solution (Mamawi et al., 2020). The IMOs are able to decompose and convert complex organic compounds, mainly ammonia and hydrogen sulphide into simple odourless gases (Anyanwu et al., 2015). The diagrammatic representation of how IMOs can reduce odour emissions is shown in Figure 3.

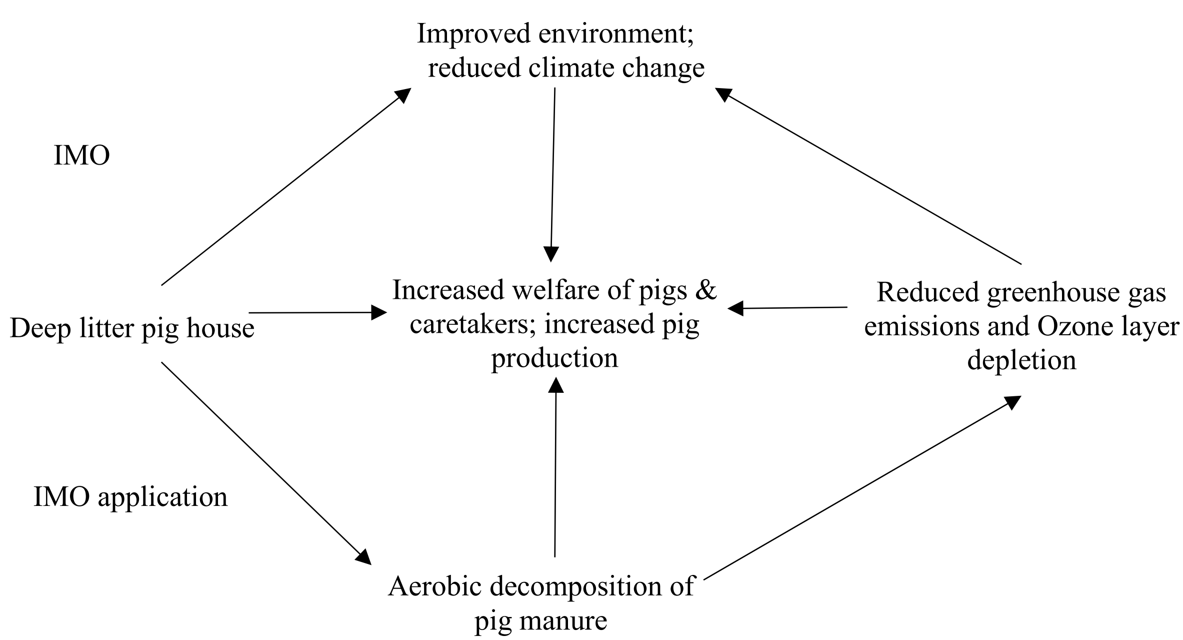

Figure 3: Use of IMO as an alternative approach to odour control and environment improvement

3.0 CONCLUSIONS

The use of IMOs in pig production systems has a great potential of reducing offensive odour and greenhouse gas emissions to the environment, hence minimising Ozone layer depletion and effects of the climate change. Although deep litter floor treated with IMO solution does not completely eliminate bad odour from pig houses, it reduces odour intensity to a level that is environmentally friendly and acceptable to the people living around the pig houses. However, there is low adoption of this initiative probably because of minimal knowledge on the procedures in the preparation of the IMO solutions. Thus, including this initiative in extension systems of different countries would contribute to the adoption of the initiative and thereby reduce resentment toward pig production in different communities.

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CONFLICT OF INTEREST

The authors declare no known conflict of interest

AUTHOR CONTRIBUTION

Preparation of draft manuscript, EKN; Review of manuscript and final formatting JSK. All authors agree to the information provided in this manuscript.

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