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An Overview of Microbial Fermented Feed and its Impact on the Poultry Industry

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ABSTRACT

The poultry sector typically accounts for approximately 26% of the total meat production in several countries. However, the poultry sector is grappling nowadays with a rising problem of substandard meat production, owing to the usage of low-quality feed for the chicks. Previous studies have indicated to improve the quality of chick feed, however, researchers are still trying to improve the quality of feed by refining its shelf life and nutritional contents. Fermentation of various agricultural products, other than traditional feed, such as rice husk, palm kernel cake, wheat bran, potato pulp, banana peel, corn seed meal is carried out by using bacterial and fungal cultures to increase the production and quality of chicken feed. Although all these additives have the potential to be used as a replacement for traditional feed, nonetheless the main issue lies in the increased cellulose and fiber content. These constraints are being removed by using bacterial and fungal strains, especially those that are reported to have cellulose digestion and various enzymatic activities. Each strain has its own optimized fermenting conditions, such as solid-state fermentation or submerged fermentation, in which it yields its maximum output, before fermenting any feed with a specific microbe. These optimized conditions and techniques must be monitored in order to get the desired upshot. Therefore, this review article focuses on different substrates fermented by a variety of microbial strains along with their effectiveness and their future prospects. Furthermore, this study aims to suggest an alternative resource, which can be used to meet the poultry needs of the increasing population.

Keywords: microbial fermentation, optimized fermenting, poultry industry, solid-state fermentation, traditional feed

1. INTRODUCTION

Proteins are an important part of the human eating/dietary routine. There are predominantly two sources of proteins, namely plants and animals.

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Reportedly, around 66% of the Pakistani population is facing protein malnutrition due to an inadequate amount of protein intake in their diet [1]. An average requirement of an individual protein intake is 103g per day, meanwhile the available amount is only 70 g per day [2]. In Pakistan, sheep, beef, poultry meat, milk, and eggs are the principal sources of animal proteins. Additionally, poultry meat contributes significantly to the market needs of proteins, which can be advanced by enhancing producer's benefits and by reducing retail cost. Nearly, 1.7 million people are associated with the poultry for their financial needs [3].

Pakistan is an agricultural-based company/country in which livestock farming plays an important role in the economic growth of the country. In the livestock industry, the poultry sector is of prime importance as it provides opportunities to a number of local farmers [4]. Pakistan is also stratified as the 11^{th} position holder and one of the largest poultry production countries globally with 1.05 billion broilers being produced annually. Consequently, this zone subsidized approximately 30% of meat production [5]. On the global level, the primary poultry products production is showing a rapid increase due to their increased consumption because of the increased population as it is preferred by consumers due to high quality and relatively cheap access to people. Statistics have indicated an increase demand for these poultry products per annum [6].

This demand is continuously increasing but is becoming more difficult to fulfill as most of the local and small-scale farmers are facing problems in the rearing of a significant number of chickens/The demand for meat production is rapidly increasing, yet meeting this demand is becoming a demanding challenge, which the local and small-scale farmers are facing these days. The factors that were considered important during the discussion with respondents were a lack of financial credit, inadequate current poultry equipment, a lack of strategic support, a lack of good knowledge about poultry raising, the absence of government assistance, and competent direction [7].

In addition to these elements, the feed given to the broilers in this industry is of utmost significance and its poor quality or a supply-demand imbalance might directly affect meat production. The broilers' diet is a pivotal variable, as the formulation of poultry feed greatly/significantly impacted their growth and development and health and quality of ultimate outcomes, such as eggs and meat. As a result/Resultantly, the poultry

industry is in desperate need of feed additives that provide the intended outcomes, while using the least amount of resources, ensuring the health of the people using them, and the safety of the final product. Numerous studies have focused on promoting the best feed formulation conditions that are cost-effective while taking into account the physiology, gastrointestinal capacity, and digestive flora of broilers [8].

Balancing the quality and quantity of chicken feed is crucial for meeting the fundamental challenges, however, the real struggle is over whether to include feed additives that might improve the health of broilers and have other positive effects. Earlier/Previously, techniques for improving the nutritional value/quality of unconventional feed ingredients for broilers were linked to the process of fermentation. Latterly, the fermentation process has been used to give practical feed formulations that have the potential to improve the health and productivity of broilers and the microecology of their gastrointestinal tracts [9]. Although fermentation is the best method for creating feed additives like amino acids, proteins, enzymes, and direct-fed microorganisms in the poultry feed industry, however, currently much attention is given to feed fermentation development and the creation of fermented goods. Understanding the microbiological science of feed fermentation as well as the impact of these modified feeds on digestibility and biosafety are included in this [10].

The target of attaining the maximum outcomes of the fermented feed can be achieved by various ways of fermentation, in this regard solid-state fermentation and liquid-state fermentation are the most common and effective ones [11]. Reportedly, it has been proved that under the same set of conditions, various substrates used in fermentation would definitely lead towards a variety of products, each having its unique characteristics [12]. Significantly, the process of fermentation needs a set of controlled conditions regarding different factors in which any change can affect the overall process, ultimately affecting the product. For this purpose, a controlled temperature, dissolved oxygen, carbon dioxide, pH, and nature and composition of media for fermentation is required [13].

Nowadays, fungal and bacterial inoculums in fermented feeds are widely being used to get certain desired results comprising many anti-pathogenic activities, which not only escalate the life expectancy of broilers but they are also responsible for decreasing the susceptibility of illness against pathogens. As a consequence of the growing needs, the biosynthesis

of nanoparticles has received more attention to promote eco-friendly and safe improvements for the synthesis of nanoparticles. Most importantly/Significantly, the antimicrobial action of silver nanoparticles was checked through proper systematic ways, which proved that these nanoparticles are very effective against various pathogenic or disease-causing bacteria and fungi infections [14]. Moreover, the bacterial and fungal cultures are found to synthesize various enzymes and proteins, which have a greater impact on the enhancement of resistance against various pathogens and breaking the fiber of feed resulting in better digestion of feed by broilers [15].

1.1. Fermentation

Fermentation is a deep-rooted method that has been used for years to extract some beneficial products but now with the aid of technology and research, we are getting more optimized and desired products. The essential goal of fermentation of agricultural products and by-products is not only their preservation but their prime purpose is to enhance their nutritional content [16]. This knowledge of fermentation is now utilized for the poultry sector as well to produce a fermented feed that can improve the nutrient content of feed and also the resistance of broilers against microbial pathogens.

1.2. Types of Fermentation

Numerous strategies are accessible for the mass production of fermented feeds, including solid-state and liquid fermentation, which have been generally utilized in the course of recent years. Solid feed can be supplemented with fermented milk for young individuals. Even though the process of fermentation could be carried out spontaneously, it might not be useful in practical use as there can be harmful microbes and harmful metabolites [17]. In order to turn the table around in our favour we need to optimize the conditions so that harmful metabolites cannot affect our product or may not get a chance to accelerate; these conditions must be regulated as for feed formulation we need a product that is free of any kind of toxic metabolites and should not have any negative impact on our animals.

Fermentation process is further divided into two types, namely submerged fermentation and solid-state fermentation [18].

1.3. Submerged Fermentation

Liquid fermentation or submerged fermentation is a type of fermentation in which the collected substrate is in a liquid medium and is inoculated with broth cultures [19]. Submerged fermentation has an advantage over the solid-state in terms of immense microbial growth and higher digestibility of feed contents [10]. SmF methodology is a prevailing technique in the proliferation of probiotics in research and the medical industry [20].

The percentage of water is an important factor in the growth of individuals fed with fermented feed prepared through SmF. This factor can enhance the growth of the animal as well as inhibit it [21]. The feed is stored in a tank where water content is adjusted usually there is 1:3 of feed and water [22], which is then inoculated with the culture. After drying this fermented feed, this feed is given to the animals [23], it gives a more stable pH range, which affects broilers' gut microbiology [24] and this low pH, in most cases, fortifies the ability of the stomach to act as the first line of resistance against any potential pathogenic infections [23].

Apart from its benefits, trials with liquid fermented feed in the poultry sector are inadequate because it is believed that wet feed is less appropriate for the species as it can causes wet debris [24]. Due to the presence of a greater amount of water or moisture content the prepared feed is difficult to handle, which is why fed individuals also had worse hygiene scores [25] this can occur due to the mismanagement of feed process.

1.4. Solid-State Fermentation

It is an entirely different technique from SmF as it deals with a solid substrate and inoculum that is inoculated on that moistened solid substrate. SSF is preferred over SmF for feed fermentation due to various substantial reasons, which has gathered the attention of researchers and industrialists.

Relative to fluid fermentation, SSF enjoys the benefits of creating less waste water, more stability in terms of structure and composition, usage of lower energy during the process, and ease of carriage of the feed over the place [26]. SSF was found to be a best-suited medium for the extraction of various kinds of enzymes and this methodology was followed in extracting α-amylase by using various agricultural by-products as substrates [27]. This enzyme is commercially applicable in multiple industrial consumptions, including the liquefaction of starch, the brewing industry, the textile sector,

pharmaceutical companies, the paper industry, toxic litter removal, and others [28].

SSF is considered more suitable for the production of fermented feed for broilers as wet feed is reported to cause aggressive behavior among individuals in some cases [29]. So, if we want to get our desired productivity with no or little effect on chickens a trail of SSF should be followed.

Table 1. Differences between Types of Fermentation

Submerged Fermentation	Solid-State Fermentation
Uses liquid media/substrate	Uses moistened substrate
Enhanced microbial growth	Microbial growth is limited
The product is less stable and is sensitive to contamination	More stable product
Difficult to handle and store	Easy to handle
Production of wet litter	High hygienic value as compared to SmF

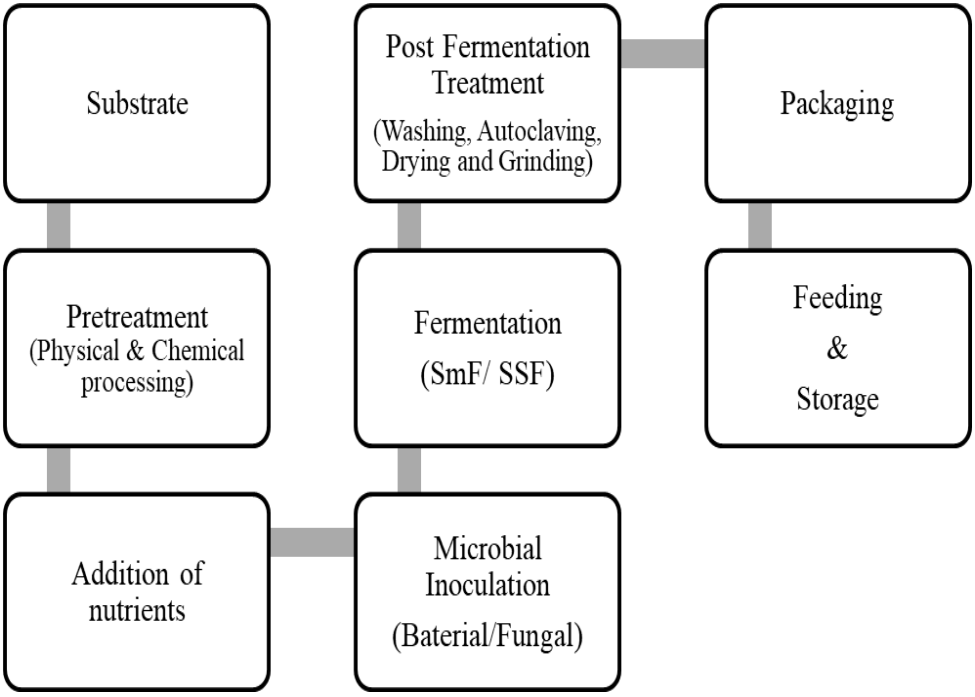

Figure 1. A Schematic Presentation of The Commonly Used Poultry Feed Formulation Method

1.5. Fermentation Feedstuff

Although a lot of feeds have the potential to be used as a substrate for making the poultry feed and various agro wastes are found quite suitable but the main obstruction to using them as a feed is their high fiber content. This high fiber is also a prime cause of hindrance in using these agro by-products as a substantial feed for the poultry sector.Cellulose present in them is not digested by the chicken due to lack of cellulase enzyme, which can cause major issues in the inhabitants [30]. A variety of unconventional substrates are used as feedstuff for fermentation in the poultry industry, including rice husk [31, 32], palm kernel cake [33, 34], wheat bran [35], potato peel and pulp [36], banana peel [37] corn seed meal, and many other by-products; but still, only limited research is available on the concerned topic

The selection of substrate or feedstuff is a key factor, while designing fermented feed for the poultry purpose. Choosing a less-deficit or low-nutritious substrate as feed will not give a desired output, having better efficacy. The selected substrate must follow certain prerequisites, such as it should be easily available, easy to handle and manage, having the capacity to be processed by microbe added, such as having good fermentation ability, and must be sustainable to chemical or physical processing. It should not be a substrate that could cause any toxic litter and couldn't accumulate any sort of toxic metabolites in it. The more inert substrate would lead to the formulation of more effective feed and could undergo SmF as well as SSF.

Hence, utilizing unconventional feedstuff is efficient that can only be done by using various agro products as feedstuff, which are a cheap replacement for standard poultry feed, but they also reduces waste from our environment [38].

1.6. Microbial Additives

The addition of probiotics in the feed is found to be quite effective in enhancing the nutritional value of feed, which increases its protein content and decreases the fiber content. Most of the microbial fermented feed is also found to improve digestibility by refining villus length and height [39]. Moreover, these probiotics could also improve gut microecology, which results in more developed pathogenic resistance [40]. Many fungal and bacterial strains are being used only because of their anti-pathogenic character [41]. These can be used as additives in feed to enhance the

microbial resistance of animals, such as *Saccharomyces cerevisiae* is found certainly effective in inhibiting the growth of many bacterial strains [42].

A significant trial proved that fermented feed enhanced the feed conversion ratio and gut health of broilers, especially when fed with the finisher feed because of the presence and activity of coliform and lactobacillus strains in the feed. Precisely, the length of villi of the small intestine was shown to be grander and the microbiota of the gastro intestine was shifted in a beneficial way. However, feeding fermented feed to young chicks can restrict their growth. Therefore, feeding chicks with the fermented feed in the finisher phase is more advisable to gain more efficient outcomes [2]. Mostly in the formulation of fermented feed, it is preferred to ferment the substrate with lactic acid bacteria due to its unique and striking traits. Homolactic fermentation is being used to improve palatability of feed [30]. LAB also aids in the breakdown of anti-nutrient factors, which in return increases the absorption of minerals in the body and also magnifies the availability of different nutrients (Cu, P, Mg & Ca) [43]. An increase in protein proportions like histidine, lysine, and methionine were also observed. Moreover, the addition of lactic acid bacteria helped in the degradation of indigestible carbohydrates and the rapid fabrication of organic acids mainly lactic acid [44]. Another research was also conducted (using palm kernel cake as substrate) to check the digestion changes in the inhabitants' by comparing the ileum digestibility (of amino acids and crude protein) both in fermented palm kernel cake and unfermented palm kernel cake. *Paenibacillus curdlanolyticus* and *P. polymyxa* were being used in solid-state fermentation of the feed fermentation. The results revealed that the process of fermentation by these bacteria not only improved the levels of crude protein, but it also increased the digestibility of amino acids along with a decrease in the fiber ratio as well. An enhanced nutritional portfolio was also reported [45].

Another research concluded that the fermentation of cottonseed meal by using *Aspergillus niger*, *Aspergillus oryzae,* and *Bacillus subtilis* gave noticeable outcomes. This fermented cottonseed meal in the diet of broilers improved the inhabitants performance by creating a balance between the micro-flora of the intestine and refining the morphology of the intestine. In a nutshell, the positive outcomes of a fermented cottonseed diet were noticed in the health and performance of inhabitants, which recommended that this refined foundation of protein could be used as an effective

alternative for the standard poultry feed [46]. Plant extracts, such as pangola-grass and napiergrass are among the most common fodder grasses that were also being utilized and proven as potential solid substrates as a resource of protein. Solid-state fermentation of fodder with competent microbes such as *Entrophospora* sp., *Bacillus subtilis*, and other cellulolytic microbes increased the protein content and improved the digestibility in the broilers. Inoculation of suitable microbes particularly for solid-state fermentation in order to transform the herbage into chicken feed is the new soon-to-be technique for different sectors such as animal husbandry, agriculture and ample management [47].

Fermentation of wheat bran by white rot fungi amplified the activity of various ligno-cellulolytic enzymes, which also increased the intensities of active components that further control the expression of targeted molecules having antioxidant activity in poultry feed which ultimately increased the shelf life of feed [48]. Research on a by-product of the shea fat industry that is shea nut meal also proposed some positive outcomes. *Aspergillus niger* was used as an inoculum or microbial additive in the fermentation of shea nut. The growth performance of the broiler was evaluated. The broilers fed with fermented feed showed an increase or higher growth enactment than those inhabitants who were fed with the unfermented feed. Also, the live weight gain of both broiler groups was compared, and it was observed that broilers fed with the fermented diet showed a higher tendency of weight gain than the broilers fed with the control diet or unfermented diet [49].

The capability of microorganisms as biotechnological tools for significant enzymes has invigorated interest in the investigation of organisms having extracellular amylolytic action. The capability of *Paenibacillus amylolyticus* for the synthesis of α-amylase has also been investigated. In this specific situation, different farming by-products (rice husk, wheat bran, maize bran, and rice bran), banana and potato peel were treated as strong substrates for α-amylase synthesis [27]. Similarly,, fungus isolates were also being used in the production of different enzymes or drugs, for example, *Aspergillus terreus* was being used in the production of lovastatin, which is a high-value molecule and its presence in the feed showed positive impact on the health of inhabitants [50]. This knowledge could be exploited in the feed formulation for the extraction of significant enzymes or molecules.

2. CONCLUSION

With the increasing population, the demand for meat production is also increasing day by day. Since more meat is required to fulfil the population's needs, an increase in the population tends to put more pressure on the poultry industry. However, in order to maximize production, quality must be prioritized for good quality meat production. In order to gain healthy inhabitants one must have good fermented feed for that purpose, which can only be fermented through feed formulations and should be revolutionized by using the maximum amount of resources available, such as agricultural or agro wastes . These feeds have a lot of potential to be used for inhabitants, especially for chicken but the only drawback of using these feeds for chicken is that they are high in fiber, which can be reduced by using appropriate microbial additives and effective fermentation techniques. Microbes such as Asergillus, Paenibacillus, Saccharomyces, Bacillus, and LAB has already been tested for their unique traits like increase in digestibility, anti-pathogenic activity, and extraction of enzymes. The best selection of fermentation technique and microbe used can give the desired outcomes. Even though the current changing trend is focusing on fermented poultry feeds, there is still a lack of information, and more research can produce better results. Future research can study the optimization of conditions and get more benefits from the above-discussed substrates to help the poultry industry in the coming future.

CONFLICT OF INTEREST

The authors of the manuscript have no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

DATA AVAILABILITY STATEMENT

Data availability Statement: Data availability is not applicable as no new data was created.

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