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A solid state fermentation, its role in animal nutrition: A review

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Abstract

The huge nutritious potential of agricultural based byproducts has generated an interest of nutritionist for utilizing these efficient ways and improves the production of animals. In concern to this, solid state fermentation (SSF) is a promising novel technique. The lignocellulosic structural characters of plant residues provides a solid support and act as a substrates for the microbial fermentation to produce a certain value added products through SSF. SSF has a wide scope in the field of animal nutrition in terms for the production of enzymes, bioactive components, organic acids, vitamins, and feed additives, bio transforming products, biological degradation and detoxification of agricultural residues/wastes. The inclusion of SSF biomass has a great impact on nutritive composition of feed, performance, hemo-biochemical status, gut morphology, gut microbiota, carcass attributes, rumen fermentation along with the reduction in enteric methane emission of animals and poultry birds. This review highlighting a most imperative technique of SSF and its positive influence on improve digestibility of crop residues along with betterment of gut health, health status and ultimate performance of ruminants and non ruminants animals and birds.

Keywords: Solid state fermentation, lignocellulose, crop residues, substrates

Introduction

Solid state fermentation (SSF) is the fermentation process where microorganisms are grow in an environment without free water, or with very low content of free water on solid substrate and complex material is converted into simpler forms, moreover this solid substratum itself act as carbon/energy source (Murthy *et al*. 2018) [39]. Egyptians were reported to make bread using a notable technique SSF and has been used in Asian continent from the ancient time in 2000 BC (Pandey *et al*. 1992) [45]. In natural condition with little moist or in near absence of water, the microorganisms obtain carbon, nitrogen and other nutrients for growth and show degradative activity. In recent years, SSF has shown much development in bio processing in food, pharmaceutical, textile, biochemical and bioenergy. Solid state fermentation is processed through fungi, bacteria or yeast (Pandey, 2003; Soccol and Vandenberghe, 2003) [46, 60].

With an increasing the expansion of agro-industrial activity, accumulates a bulk quantity of residues over every year (Mahesh and Mohini, 2013; Sadh *et al*. 2018) [29, 53]. These agricultural based biomass are highly lignified as per the composition and having lignocellulosic in nature, that causing an elimination issue with ultimate environmental pollution (Koyani and Rajput, 2015) [25]. Worldwide bid of animal based products are augmented in a blooming rate thus emphasizing the inevitability of applying strategies to improvise animal productivity (Sujani and Seresinhe 2015) [66]. The major constraints in livestock's sector have lack of availability of feed resources, poor quality of available feed sources, and high feed cost particularly in tropical countries. The worsening animal health and their sustainability have necessitates the use of certain substitute such as agricultural by products, crop residues and grasses as a feed source (a lignocellulosic biomass) (Shrivatava *et al*. 2014) [57]. These agro industrial residues used for animal feeds, having highly lignified fiber, poor in nitrogen and minerals, reduced digestibility and contains anti nutritional factors, owing to this these, are not to utilized judiciously and therefore they are receiving more consideration for quality control (Graminha *et al*., 2008) [20]. In view of high nutritional perspective these residues are not described as a waste but known to be as raw materials for further product formation and developments (Sadh *et al*. 2018) [53]. With an advance, in a field of animal nutrition, animal nutritionist developed various physical, chemical and biological methods to overcome the problem associated with animal's feed stuffs (Sujani and Seresinhe,

2015) [66]. As a biological treatment has fascinated an interest of researchers and it has become a widely discussed theme in a current period (McAllister *et al.* 2003; Sujani and Seresinhe, 2015) [34, 66]. Thus, aim of this review is present applications of SSF in animal nutrition and highlighting the beneficial effects of including SSF biomass in animal feed for the health status and performance of animals or poultry birds.

Types of fermentation

There are two type of fermentation process namely solid state fermentation (SSF) and Liquid or submerged state fermentation (SmF). Solid state fermentation (SSF), a process that takes place in a solid matrix (inert support or support/substrate) without or with smaller quantity of free water (Singhania *et al.* 2010) [59], however, moisture needed to support the growth and metabolic activity of microorganisms (Thomas *et al.* 2013) [69] on solid substrate. On the other hand, in liquid-state fermentation (LSF) the substrate is solubilized or suspended as free particles in a large volume of water (Chahal, 1983) [10] The differentiating feature between SSF and SmF has been described in Table 1.

Table 1: Differentiating points in SSF and SmF.

Features	SSF	SmF
Medium	Not free – flowing	Free flowing
Deepness	Shallow	Greater
Nutrients	Solid substrate	Employed
Water	Medium absorbs	Medium is dissolved
Temp., pH	Not uniform	Uniform
Contamination	Less	Higher
System	3 phase	2 phase
Intra particle resistances	Present	No such resistances
Culture distribution	Adhere to solid and grow	Uniformly distributed
Bioreactors	Small	Large
Measurements of biomass	Lots of difficulties	Online sensors are available
Product	Highly concentrated	Low concentration
Liquid waste	Not produced	High quantity

Source: Prabhakar *et al.* 2005 [47]; Koyani and Rajput, 2015 [25]

Solid state fermentation

Solid state fermentation (SSF) is recognized a biotechnological processes in which in the absence or near absence of free water organisms grow on non-soluble material or solid substrates (Bhargav *et al.* 2008) [6]. It involves microbial fermentation of byproducts with few processing steps. At the most general level, the major processing steps of SSF are not different from those of a submerged liquid fermentation (SLF) process. The processing steps of solid state fermentation involves (Manan *et al.* 2017 and Sadh *et al.* 2018) [31, 53] are as follows.

General processing steps in SSF process

1. Inoculum preparation
2. Substrate selection and preparation
3. Bioreactor preparation
4. Inoculation and Loading
5. Bioreactor operation
6. Unloading
7. Downstream processing
8. Waste disposal

Characteristics of the fibrous components of crop residues

The major portion of the agricultural residues are carbohydrates mainly lignocellulose. (Ravindran *et al.* 2018) [51]. These Cellulose, hemicellulose and lignin bonding in the cell wall matrix need to be broken (Colombatto *et al.* 2003) [13]. The dietary fibers components of plant walls are influenced by both the content and physical characteristics of wall polysaccharides such as degree of crystallinity and polymerization thus not completely digested by enzymes of the animal's digestive system (Fritz *et al.* 1990) [18]. With increasing the plant maturity lignin content is also elevated and has directly impacted on digestibility of neutral detergent fiber (NDF) and it has a correlation with other nutrient utilization (Caballero *et al.* 2001) [8].

Use of certain alternative options such as the agricultural crop residues and grasses (lignocellulosic biomass) as animal feed stuffs. If these are utilized judiciously this may provide enough energy and nutrients to the animals. However, high lignin content and lower digestibility, protein content and poor palatability of crop residues and grasses discourage their use as the sole animal feed. Lignin, being a cementing material in plant cell wall restricts the fullest accessibility of carbohydrates, the energy reserve, to the microorganisms inside the gut of ruminating animals (Shrivastava *et al.* 2014) [57]. Among various microorganisms known for lignin degradation, white- rot fungi (majorly basidiomycetes) have been adjudged most promising lignin degraders and have been largely studied for bioconversion of plant residues into nutritionally digestible animal feed under solid-state fermentation (SSF) conditions (Kuhad *et al.* 1997; Tuyen *et al.* 2012; Basu *et al.* 2002) [26, 70, 4].

Table 2: Some lignocellulosic wastes and their percentage compositions.

Lignocellulosic waste	Cellulose (wt %)	Hemicellulose (wt %)	Lignin (wt %)
Barley straw	33.8	21.9	13.8
Corn cobs	33.7	31.7	6.1
Corn stalks	35.0	16.8	7.0
Cotton stalks	58.5	14.4	21.5
Oat straw	36.2	27.1	17.5
Rice straw	36.2	19.0	9.9

Rye straw	37.6	30.5	19.0
Soya stalks	34.5	24.8	19.8
Sugarcane bagasse	40.0	27.0	10.0
Sunflower stalks	42.1	29.7	13.4
Wheat straw	32.9	24.0	8.9

Source: Nigam *et al*. 2009 [41]

Application of SSF in Animal Nutrition

Solid state fermentation has an extensive scope and a novel technology in the field animal nutrition for utilizing these highly lignified by products. SSF having wide no of applications (Table 3) includes enzyme production, bioactive metabolites, organic acids production, vitamins, biological degradation of anti-nutritional factors from the various byproducts and animal feed stuffs. Enzymes are important products obtained from microorganisms and useful for human as well as animals and birds. Enzyme production is higher in solid state fermentation (Pandey *et al.* 1999) [44]. Plant cell wall has two phases including micro-fibrilar phase, it contains micro fibrils of cellulose and second is matrix phase (non-crystalline phase) which contains polysaccharides (Pectin and hemicelluloses), proteins and phenolic compounds (Brett and Waldron, 1990; Maleki *et al.* 2016) [7, 30]. Recently renewed interests have been seen in enzyme production, mainly celluloses, xylanases, Xylanases, Laccases etc. Besides bacteria, fungi are considered the best source of enzyme production through the SSF. The various substrates and microbes used for the production of various products used for feed stuffs are shown in Table 4 and 5.

Effects of SSF biomass supplementation in animal feed

The SSF biomass revealed enhance the nutritive value by relaxing the fiber matrix with increase nitrogen content of residues (Mahesh and Mohini, 2013) [29]. On supplementation in animal feed, improve nutrient utilization, health status, gut health and productive performance along with reduction in methane emission of ruminants and non- ruminants.

a) Effect of SSF on nutritive/chemical composition of crop residues

In vitro study of cell wall composition of a fungal (*Crinipellis* sp. RCK-1) treated wheat straw revealed 40% increasing in the crude protein (CP)% along with 28.26% and 16.06% degradation of lignin content in 100g and 500g of substrates, respectively (Shrivastava *et al*. 2014) [57]. In same trend, two-stage fermentation with *Bacillus subtilis* followed by *Enterococcus faecium* effectively reduced anti nutritional factors (ANFs) soy antigenic protein, neutral detergent fiber (NDF) and phytic acid in corn-soybean meal mixed
feed and increased the trichloroacetic acid soluble protein (TCA-SP) and CP content. The amounts of soybean antigenic proteins (β-conglycinin and glycinin) in mixed feed were significantly decreased after first-stage fermentation with *Bacillus subtili.* In addition, inoculated mixed feed following two-stage fermentation contained greater concentration of crude protein (CP), ash and total phosphorus (P) compared to uninoculated feed, whereas the concentrations of neutral detergent fiber (NDF), hemicellulose and phytate P in fermented inoculated feed declined ($P<0.05$) by 38%, 53% and 46%, respectively (Shi *et al*. 2017) [56].

Table 3: Applications of SSF in animal nutrition

Economic Sector	Application	Examples
Industrial Fermentation	Enzymes production	Amylases, amyloglucosidase, cellulases, proteases, pectinases, xylanases, glucoamylases
	Bioactive products	Mycotoxins, gibberellins, alkaloids, antibiotics, hormones
	Organic acid production	Citric acid, fumaric acid, itaconic acid, lacticacid
	Biofuel	Ethanol production
	Miscellaneous compounds	Pigments, biosurfactants, vitamins, xantham
Agro-Food Industry	Biotransformation of crop residues	Traditional food fermented (Koji, sake, ragi, tempeh), protein enrichment and single cell protein production, mushrooms production.
	Food additives	Aroma compounds, dye stuffs, essential fat and organic acids
Environmental control	Bioremediation & biodegradation of hazardous compounds	Caffeinated residues, pesticides, polychlorinated biphenyls (PCBs)
	Biological detoxification of agroindustrial wastes	Coffee pulp, cassava peels, canola meal, coffee husk

Source: Guerra *et al.* 2003 [21]; Mienda *et al.* 2011 [36].

Table 4: Microorganisms used for SSF

Microorganisms	Substrates/ Solid supports	Source
Bacteria		
Amycolatopsis Mediterranean MTCC 14	GOC and COC	Vastrad and Neelagund (2011a,b) [71, 72]
Pseudomonas spp. BUP6	GOC, COC, SOC, and CSC	Faisal *et al*. (2014) [17]
Bacillus licheniformis MTCC 1483	Wheat straw, sugarcane bagasse, maize straw, and paddy straw	Kaur *et al*. (2015) [24]
Fungi		
Aspergillus niger	Rice bran, wheat bran, black gram bran, GOC, and COC	Suganthi *et al*. (2011) [63]
Aspergillus oryzae	Soybean meal (waste)	Thakur *et al*. (2015) [68]
Rhizopus arrhizus and *Mucors ubtillissimus*	Caorn cob cassava peel, soybeans, wheat bran, and citrus pulp	Nascimento *et al*. (2015) [40]
Aspergillus niger	Rice bran, wheat bran, black gram bran, GOC, and COC	Mahalakshmi and Jayalakshmi, (2016) [28]
Aspergillus terreus	Palm oil cake	Rahman *et al*. (2016) [49]

Source: Sadh *et al.* 2018 [53]

Table 5: Substrates used for SSF

Enzymes	*Microorganisms*	Substrates/ Solid support	Source
Lipase	*Candida rugosa*	Groundnut oil cake (GOC)	Rekha *et al*. (2012) [52]
Pectin methyl Esterase	*Pseudomonas notatum*	Wheat bran and orange peel	Gayen and Ghosh (2011) [19]
Lipase	*Pseudomonas aeruginosa*	Linseed oil cake (LOC)	Dharmendra, (2012) [14]
α-Amylase	*Aspergillus niger*	Orange peel	Sindiri *et al*. (2013) [58]
α-Amylase	*Aspergillus oryzae*	Coconut oil cake (COC)	Ramachandran *et al*. (2004) [50]
α-Amylase	*Bacillus sp.*	Rice bran	Sodhi *et al*. (2005) [61]
α-Amylase	*Bacillus sp.*	Corn bran	Sodhi *et al*. (2005) [61]
α-Amylase	*Aspergillus niger*	Rice bran, wheat bran, black gram bran, and soybean	Akpan *et al*. (1999) [1]
Invertase	*Aspergillus niger*	Fruits peel waste	Mehta and Duhan (2014) [35]

Source: Sadh *et al*. 2018 [53].

B. Effect on Performance

Many researchers suggested a positive effect of SSF fermented feed on performance of animals. Yasar *et al*. (2016) [75] reported supplementation of fermented wheat, barley and oat revealed significant improvement in body weight, feed intake and feed conversion ratio (FCR) of broilers at days 21 and 42. Similarly, Yasar *et al.* (2017) [76] noticed a significant increases in weight gain and improvements in feed conversion ratio in broiler chickens fed the diets supplemented with 5.0 and 10 g/kg of YFA (Yeast fermented feed additive) and NYFA (Non-yeast fermented feed additive) at 42nd days of age. Alike effect with better growth performance was obtained when maize was replaced at 75% fermented cassava meal (FCM) reported by Kanyinji and Moonga, (2014) [23]. Further, Shahzad *et al*. (2016) [55] reported that higher Average Daily Gain, digestibility, FCR, feed economy and lowered feed cost in Niliravi buffalo calves on feeding of fermented wheat straw containing total mixed ration. Pan *et al*. (2018) [43] revealed that feeding of *Trichoderma* fermented rice straw significantly increases in digestibility of dry matter (DM), neutral detergent fiber (NDF) and acid detergent fiber (ADF) and nutrient utilization in Barbados Sheep. An increasing trend in milk production (linear, $P \leq 0.10$) with the increasing level of *Saccharomyces cerevisiae* fermentation product (SCFP). Moreover, Supplementation of SCFP linearly increased ($P<0.05$) the N conversion, without affecting rumen pH and ammonia-N ($P>0.05$). Increasing level of SCFP linearly increased ($P<0.05$) concentrations of ruminal total volatile fatty acids, acetate, propionate, and butyrate, with no difference in molar proportion of individual acids ($P>0.05$) in dairy cows reported by Zhu *et al*. (2017) [80].

C. Effect on Haemato-Biochemical Parameters and Antioxidant Status

Wang *et al.* (2017) [74] noted elevated activities of serum glutathione peroxidase level (GSH-Px) and total superoxide dismutase (T-SOD) in broiler birds fed fermented cotton seed meal (FCSM-1) diets were greater than that in the cotton seed meal (CSM) group on day 21 ($P<0.05$) and level of serum malondialdehyde (MDA) was lower and the greater activities of serum total antioxidant capacity (T-AOC) and GSH-Px with lower down ($P<0.05$) the serum MDA level on 42nd day in birds fed fermented cotton seed meal (FCSM). In addition, better effect of FCSM with decreased levels of serum total protein (TP), albumen (ALB) and blood urea nitrogen (BUN) were observed by them on days 21 and 42 ($P<0.05$) than the cotton seed meal (CSM) diet. Alike that, Pan *et al*. (2018) [43] concluded that 25% substitution of Bermuda hay with *Trichoderma*-fermented rice straw in the diet of Barbados sheep could increase inhibit lipid oxidation ($P<0.05$) when compared to unfermented rice straw. Muhammad and Oloyede, (2009) [38] reported significant effect with improvement in

level of hematologiocal indices includes hemoglobin (Hb), red blood cells (RBC), packed cells volume (PCV), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), white blood cells (WBC) and platelets within the range with broilers fed with *Aspergillus niger*-fermented *Terminalia catappa* seed meal-based diet than the raw *Terminelia catappa* seed meal-based diet. In

corroborated findings observed by Sugiharto *et al*. (2016) [65], at day 21 in broilers supplemented with 80-CP-AC (cassava pulp-*Acremonium charticola*) and 240-CP-AC groups had lower ($P<0.01$) H/L ratio as compared to other chickens while higher leukocytes counts were observed in chickens fed with 240-CP-RO (cassava pulp-*Rhizopus oryzae*) and 160-CP-ACRO (Acremonium *charticola-Rhizopus oryzae*) groups the other groups. Thus, the significant effect of fermented feed on hemobiochemical and antioxidant status supports resultant improvement in health status of animals or birds.

D. Effect on Gut Morphology

The intestinal mucosa protects the sterile internal milieu from hostile luminal contents and it defends against harmful dietary substances and pathogens and has crucial functions in the digestion and absorption of dietary nutrients (Sugiharto *et al.* 2015) [64]. Increasing the villus height is suggestive of increased surface area with greater absorption of available nutrients resultant improved gut health status (Baurhoo *et al*. 2007) [5]. While, the crypt can be regarded as the villus factory, and a large crypt indicates fast tissue turnover with a high energy demand for new tissue generation (Yason *et al.* 1987) [77]. Additional tissue turnover will increase nutrient requirements for maintenance; will therefore lower the efficiency in terms of poor growth performance of the animal. A study with chickens fed on fermentation products with 0.5% and 1.0 soybean hulls with *Pleurotus eryngii* (FSHP) groups had higher ileum villus height than control and 0.5% fermented soybean hull (FSBH) groups. Moreover, the inclusion of 0.5% FSHP in the diet showed significantly the highest villus height/crypt depth than other groups ($P<0.05$) (Lai *et al.* 2015) [27]. In same trend, a higher ($P<0.05$) ileal

villi height was recorded Teng *et al.* (2017) [67] with the 10% *Saccharomyces cerevisiae* fermented wheat (FWSC). Similarly, Chu *et al.* (2017) [12] reported significantly increased villus height and villus height/crypt depth ratio in the ileum and no morphological changes or incidences of non-specific pathological lesions investigated 10% wheat bran fermented with *Trichoderma pseudokoningii* (FWB). These available literatures proves the solid fermented feed has improves gut morphometry and morphology resultant better utilization of nutrient with improve growth performance of birds.

E. Effect on Gut Health

Gut microflora plays a vital role in maintaining gut health of poultry birds. In broilers, lactic acid bacteria belong to aboriginal microbe in the gastrointestinal tract (Mataharo *et al.* 2014; Prado-Rebolledo *et al.* 2016; Jose *et al.* 2015) [33, 48, 22] in addition lactobacilli can inhibit the growth of putrefactive and pathogenic bacteria. Study conducted by Elmasry *et al.* (2017) [16] reported decreased coliform count, while increased Lactobacilli count (8.71 log CFU/g cecum content) and Cellulolytic bacterial count (6.64 log CFU/g cecum content) in cecum of birds fed with wheat bran solid fermented by *Trichoderma longibrachiatum* (SF1), which recorded 8.55 log CFU/g cecum content, compared to diet with no wheat bran (9.51) and diet with 10% unfermented WB (9.55) log CFU/g of ceacal content. In accordance, Yi *et al.* (2016) [78] revealed that, the number of coliform bacteria was decreased in the ilea and caeca of broilers supplemented with 10% fermented wheat bran with *Trichoderma pseudo konngii* compared to the control group. A same, inclusion of fermented rapeseed meal enhanced the growth of lactobacilli in the colon and ceca compared with either the control diet or the unfermented rapeseed meal diet, reported by Chiang *et al.* (2010) [11] suggested these fermented feed induced a balanced microbial population lead a healthy intestinal tract resulting in better control of intestinal pathogen. Further, birds fed fermented cotton seed meal had greater Lactobacilli counts in ceacal digesta than other groups (*P*<0.05) reported by wang *et al.* (2017) [74].

F. Effect on Carcass Attributes

The broilers are reared form getting a wholesome quality of meat. The quality of carcass characters including organs yields and various body cuts has a prime importance in broiler industry. In concern effect with fermented feed, Yasar *et al.* (2017) [76] highest total digestive tract (TDT) weight and liver weight were obtained from the broiler chickens fed the diet supplemented with non-yeast fermented additives (NYFA) at 10 g kg−1. Along with that, significant (*P*<0.05) effect on the lengths of TDT, foregut, and small intestine with NYFA feed at 10 g kg−1.The birds fed fermented (F) cereals(Barley and Oat) produced higher carcass yields than those fed unfermented (UF) cereals (Barley and Oat) (70.2% vs. 68.8%, SEM of 0.5) moreover, the increased liver weight was also reported with the F as compared with the UF grains (3.3 vs. 3.1 g/100 g BW, SEM of 0.05) (Yasar *et al.* 2016) [75].

G. Effect on Rumen Parameters

Supplementation of ruminal fermentation modifiers have been revealed as a cost- effective and safe way to maximize feed utilization of low-quality forage, and thereby improve milk production (Eastridge, 2006) [15]. In vivo and in vitro studies have documented encouraging effects of *Saccharomyces cerevisiae* fermentation product (SCFP) on rumen fermentation (Mao *et al.* 2013; Yoon *et al.* 1996) [32, 79]. In these regards, study conducted by Zhu *et al.* (2017) [80] with supplementation of SCFP linearly increased (*P*<0.05) the nitrogen (N) conversion, without affecting rumen pH and ammonia-N (*P*>0.05). In addition, increasing level of SCFP linearly increased (*P*<0.05) concentrations of ruminal total volatile fatty acids, acetate, propionate, and butyrate, with no difference in molar proportion of individual acids (*P*>0.05). They suggested supplementation of SCFP shifted rumen microbial population to a greater energetic and nitrogen efficiency of dairy cows consuming diets containing low quality forages. Azlan *et al.* (2017) [3] revealed that no differences for acetate production for goats fed treated rice straw compared with the control group, but concentration of propionate increase significantly (*P*<0.01). Higher propionic acid concentrations would lead to an increased glucogenic potential of the diet and milk production (Zhu *et al.* 2017) [80].

H. Effect on Methane Emission

In the next 40 years, methane production as a source of greenhouse gasses from the livestock production may increase as a consequence of increased food production (O'Mara, 2011) [42]. Feed is the one of major mitigation strategy for methane production (Mitsumori and Sun, 2008) [37]. So in view of utilizing agricultural byproducts through solid state fermentation and progress to reduced methane production. A study by Wang *et al.* (2016) [73] revealed that feeding red yeast rice significantly reduced CH4 energy output and heat production (*P*<0.001), thus resulting in a higher energy retention (*P*<0.001). Goats fed the red yeast rice diet produced less CH4 (g/d) than those given the control diet and consequently had lower CH4 emission rates as a proportion of DM intake and OM intake, similar results were also obtained in terms of CH4 energy output as a proportion of GE intake (*P*<0.001), DE intake (P=0.004) and ME intake (P=0.008). *In vitro* study using a rumen simulation technique (Rusitec) decrease in CH4 production by 42% through supplementation of 150 mg lovastatin per liter of rumen liquor reported by Soliva *et al.* (2011) [62]. Further, Azlan *et al.* (2017) [3] reported that supplementation of lovastain treated feed reduced the methane production in goats by approximately 34%. When adjusted to per unit digestible DM intake, the reduction increased to 42%.

Conclusion

SSF is most imperative method used to improve the availability digestibility of fibrous crop residues by relaxing the lignocellulose network along with increasing other nutrients digestibility. Further, it resultant in to improved rumen fermentation (TVFA) range of 10 to 15% and feed efficiency of animals. Reported studies prove incorporation of SSF ingredients at the rate of 5-20% in the ration of both ruminants and non ruminants could be improves growth, production, health status with reduced methane production and economics of feeding. However, research is needed to developed methodology for making it more economical, huge biomass production at farmer's door steps. In addition, need to produce genetically modified strains of microbes, develop proper controlling parameters and experimentation for optimize the level of SSF to increase the productive performance in various species of ruminants and non ruminants animals and poultry birds.

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