Review Article

Feed potentials of *Saccharomyces cerevisiae* biomass cultivated in palm oil and cassava mill effluents

Abstract

Saccharomyces cerevisiae biomass is one of the microbes of food safety. In animals, *Saccharomyces cerevisiae* in their diets are known to play several vital roles including prevention of diarrhea and mortality, boosting of immune system, performance, milk production, fiber degradation and nutrient digestability, adsorption of toxic metal such as cadmium, stabilization of rumen pH and microorganisms. *Saccharomyces cerevisiae* have been widely cultured in several waste feedstocks' including cassava and palm oil mill effluents. Nigeria is the largest and fifth leading producer of cassava and oil palm, respectively in the world. During processing, large volume of wastewater are generated as effluents. These wastewaters are known to cause severe environmental impacts including odour pollution and bareness in receiving soil. In aquatic ecosystem both effluents could lead to eutrophication and increased acidity content. Specifically, cassava mill effluent could cause toxicity on fisheries, vegetation, ruminant animals. This study reviews the potentials of *Saccharomyces cerevisiae* biomass cultured in oil palm and cassava processing effluents for utilization in animal feed. The study showed that biomass cultured in both effluents contain high total essential amino acids (>40g/100g) compare to Food and Agricultural Organization/World Health Organization standard values (33.9g/100g) for feed. Based on proximate composition the results are also promising especially with protein content which is higher than 17%. But the yield was low (approximately 4g/l) in both effluents. In cassava mill effluents, palm oil, heat and fermentation aid in the reduction of cyanide content. Hence, there is the need for research to focus on manipulation of the environmental parameters such as pH and temperature to increase yield, nutrient content (viz: amino acids and proximate compositions). This could aid in minimizing the environmental effects associated with cassava and oil palm processing wastewater.

Keywords: animal feed, amino acid, cassava, biotechnology advances, effluents micro organisms, oil palm, yeast

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Introduction

Oil palm and cassava are major crops that are used for the productions of several products. Unlike cassava, oil palm which belongs to the palmae family is an oil crop that is used to produce palm kernel oil and crude palm oil. Of these two types of oil, crude palm oil is the most utilized oil. On global scale, palm oil is one of the most resourceful. As such,it has found applications is several sectors including biodiesel production, soup, soap, lubrications, base for polish, pharmaceutical industry, confectionary, animal feed among others.[1–8] On the other hands, cassava is a typical dietary carbohydrate crops with energy content of about 720 x10^{12} KJ/day.[9] Cassava have been ranked as fourth cheap source of dietary carbohydrate after rice, sugarcane and maize, and 5th among starch crops on global scale.[9] In Nigeria, three major variety of oil palm exists including *Dura* and *Pisifera* and *Tenera* (an hybrid produced from Dura and *Pisifera* through research and development, and its characterized by a thin-shelled fruit and improved partition of dry matter).[6] The *Tenera* produce the highest volume of crude palm oil. According to Ohimain et al.[6], about 80% of oil palm plantation in Nigeria is dominated by *Dura* and *Pisifera* varieties that are mostly found in the wild. While the rest 20% is covered by *Tenera* varieties that are mostly found in plantations. Oil palm sector including its cultivation and processing in Nigeria are dominated by smallholders et al.[10–12] Furthermore, several varieties of cassava are found in Nigeria. Most of the cassava varieties were discovered through research and development especially between 1999–2010. Nigeria is the leading cassava producing nation in the world accounting for over 20% of global production.[13–24]. Beside Nigeria, cassava is produced in several other countries including Thailand, Brazil, Indonesia, Ghana, Congo Democratic Republic, Vietnam, Angola, and Mozambique among others. In addition, a significant portion of global cassava production is carried out in Africa. On global scale, Nigeria account for about 1.5% of total oil palm production being the fifth largest producing nation. [3,4,25] Typically Indonesia, Malaysia, Thailand and Colombia are the first four largest oil palm producing nation. The production of oil palm has not witnessed any massive growth within the last decades despite the efforts of the Nigerian government to boost agricultural sector. The processing of fresh fruit bunch of oil palm into crude palm oil requires larges volume of water which often end up as waste water as previously reported in literatures.[26–36] In a similar note, the processing of cassava into gari generates larges waste water during dewatering stage. Ohimain et al.[37] estimated that about 16% of total cassava tuber end up as waste water. In developing country like Nigeria the waste water from oil palm and cassava processing are underutilized and they are seldom treated before discharging into the ecosystem. Studies have suggested that most of effluents generated by both food processors are discharged into the soil, which then percolates and/ or drain into the nearby pits, surface water etc.[23,24] The effluents have the tendency to alter the characteristics of the receiving soil, which then emits offensive odours. Odours associated with cassava and oil palm processing can be perceived from some distance up to 100 feet depending on the scale of processing and effluent discharging density as well as the duration of effluents degradation by indigenous microbes. Specifically cassava mill effluents have been reported by authors to lower the density of soil microorganisms.[38,39] On aquatic ecosystem, studies have indicated that they could cause changes with regard to histopathological, haematological, enzymes, behavioural response, mortality etc in fisheries.[21,40,41] In the soil, cassava mill effluents can also hinder germination, proper growth and productivity of some plant species.[42–45] Toxicity of cassava mill effluents to some domestic animals have been documented in literatures as well.[21] Due to the toxicity of cassava and oil palm processing effluents to the ecosystems, studies have demonstrated the potentials for utilization through biotechnological advancement. To this regard both effluents have been studied for enzymes production, biosurfactants, organic acids, bioenergy (bio-hydrogen, biogas, bioethanol, bioelectricity), cultivation of *Saccharomyces cerevisiae* biomass. Typically, Broadway et al.[46] reported that yeast and yeast-based products is essential during birth, weaning, early lactation, and enhancement of animal health and metabolism while decreasing morbidity, thereby enhancing profitability of these animals. Therefore, this study focused on feed potentials of these food processing effluents for possible utilization in animal feeds.

Biomass generations during the treatment of palm oil and cassava mill effluents with *Saccharomyces cerevisiae*

Oil palm and cassava mill effluents contain total solids, total suspended solid, acidic pH, high chemical oxygen demand, total dissolved solid, heavy metals among several other physicochemical parameters. Some of the physicochemical parameters of the effluents often exceed the limits for all categories of effluents to be discharged into the Nigerian ecosystem as recommended by Federal Environmental Protection Agency (1991). During the use of the effluents through biotechnological advancement some of the physiochemical parameters are lowered. For instance, Iwuagwu & Ugwuanyi[47] reported that *Saccharomyces,Pichia* and *Candida* species have the tendency to reduce chemical oxygen demand and pH (tending toward alkalinity) of oil palm processing mill effluents. In a similar study Izah et al.[16] reported that *Saccharomyces cerevisiae*could reduce the content of cassava mill effluents by 37.62%, 22.96%, 29.63%, 20.49%, 21.44%, 1.70%, 53.48%, 68.00%, 100%, and 74.48% for pH, conductivity, dissolved oxygen, total dissolved solid, salinity, sulphate, nitrate, phosphate, and chemical oxygen demand levels respectively, and an elevation of turbidity by 17.17%. Izah et al.[17,20] also reported that *Saccharomyces cerevisiae* have the tendency to uptake heavy metals in cassava mill effluents through biosorption. During the treatment of cassava and palm oil mill effluents by microorganisms sludge are generated. The sludge/biomass generated at the bottoms of treatment chamber have been washed, dried and estimated in literature. For instance, Iwuagwu & Ugwuanyi[47] reported maximum yield of 4.42 g/L for *Saccharomyces* species used for the treatment of cassava mill effluents. Izah[23] also reported a yield of 3.93g/L for *Saccharomyces cerevisiae*during the treatment of cassava mill effluents. Probably due to the variation in nutrients composition of the effluents yield could be different. Furthermore, environmental factors such as temperature and pH could also influence the yield and quality of the biomass as well. Unlike oil palm, cassava contain cyanide which is one the constituents that accounts for its toxicity. During treatment, studies have shown that *Saccharomyces cerevisiae* has the tendency to reduce the concentration of cyanide in cassava mill effluents and the associated biomass.[18] Typically cyanide concentration is influenced by heat treatment, additives such as palm oil and fermentation by several microbes such as *Saccharomyces* and *Lactobacillus* species.[18,23]

Feed potentials of *Saccharomyces cerevisiae*

Saccharomyces cerevisiae is one of the main species of yeast that is widely utilized in several industrial sectors.[21,48] The choice of *Saccharomyces cerevisiae* is an industrial setting could be due to their ability to breakdown sugars (i.e. glucose, maltose) to form ethanol and carbon dioxide.[49] *Saccharomyces cerevisiae* have been widely used for fermentation of different substrates. *Saccharomyces cerevisiae* is an essential microorganism that has been considered useful in animal feed to improve production and health status.[50] *Saccharomyces cerevisiae* which are used as probiotics are nutritionally high in enzymes, fatty acids, vitamin B complex, unknown growth factors and amino acids (more than 40% of total dry matter) (Sontakke, 2012). *Saccharomyces cerevisiae* cultured in cassava mill effluents have been reported to contain essential heavy metals,[20] low cyanide and cations,[18] proximate composition and amino acids.[19] Furthermore, proximate composition, amino acids, heavy metals, cations, etc have been reported in brewer's yeast.[51] Table 1 & 2 presents the proximate composition and amino acids profile of *Saccharomyces cerevisiae* biomass cultured in cassava and palm oil mill effluents respectively. Studies have shown that *Saccharomyces cerevisiae* contain crude protein, lipid, fibre and carbohydrate. Typically cassava is known as a carbohydrate crops with low protein content. But during fermentation of carbohydrate substrate with *Saccharomyces cerevisiae* the protein content is enhanced. For instance, Onyeulor and Nwaehiri[52] reported that *Saccharomyces cerevisiae* (BY 4743) could enhance the protein content of potato peels through fermentation. Aruna et al.[53] reported protein enrichment of yam peels by fermentation using *Saccharomyces cerevisiae* (BY4743). Based on Table 2, the amino acids of *Saccharomyces cerevisiae* biomass from both effluents in comparison to Food and Agricultural Organization/World Health Organization limits for single cell protein meant for animal feed revealed that the values of the essential amino acids including isoleucine, leucine, tryptophan, histidine and combination of phenylalanine, tyrosine etc were superior and/ or comparable to recommended limit for single cell protein. On the other hand the total non-essential amino acids were lower compared to Food and Agricultural Organization/World Health Organization limits[54] (Table 2), a trend that have been previously reported by Izah et al.[19] in *Saccharomyces cerevisiae* biomass culture in cassava mill effluents and Iwuagwu and Ugwuanyi[47] in *Saccharomyces* species biomass cultured in palm oil mill effluents. The values of essential amino acids suggest that they can be used for animal feed if every other nutrient constituent are adequate. Variations exist between the proximate constituents and amino acid of *Saccharomyces* species biomass cultured in both cassava and palm oil mill effluents. The different could be due to changes in constituents of the waste water as well as environmental condition (mainly temperature and pH) of effluents they were cultured. Other internal factors could also affect the nutrient composition. In a similar study, Ogbonda *et al*.[55] reported that temperature and pH influence the yield/productivity, proximate composition and amino acid of *Spirulina* species biomass.

Table 1 Proximate composition of the *Saccharomyces cerevisiae*biomass cultured in palm oil and cassava mill effluents

Proximate composition	Cassava mill effluents[19]	Palm oil mill effluents[47]
% Crude protein	17.01	27
% Crude fat/ lipid	12.57	0.83
% Crude fibre	2.71	4.7
% Moisture	7.12	-
% Ash	7.34	6.12
% Carbohydrate	56.4	35.45
Energy (kcal/100g)	407.13	-

Table 2 Amino acid profile of *S. cerevisiae* cultured in palm oil and cassava mill effluents expressed as g/100g of protein

Amino acids	Cassava mill effluents[19]	Palm oil mill effluents[47]	FAO/WHO[54]
Phe + Tyr	6.09	8.68	6.3
Tyrosine	2.24	--	-
Phenylalanine	3.85	--	-
Isoleucine	9.01	3.09	2.8
Leucine	7.02	10.25	6.6
Lysine	2.95	6.01	5.8
Methionine	1.46	5.05	2.5
Tryptophan	5.09	6.76	1.1
Valine	2.57	7.13	3.5
Threonine	2.06	3.57	3.4
Histidine	4.63	1.91	1.9
Total essential	40.88	52.45	33.9
Proline	2.28	1.87	10.7
Arginine	-	3.85	5.2
Alanine	2.01	2.97	6.1
Glutamine	-	2.95	-
Aspartic acid	5.57	2.6	7.7
Asparagine	2.01	8.54	-
Glutamic acid	4.15	11.1	14.7
Glycine	2.52	3.71	2.2
Serine	2.41	3.57	7.7
Trimethylserine	-	3.53	-
Cysteine	0.45	-	-
Pyrrolysine	0.16	-	-
Total nonessential	21.56	34.7	54.3
Total amino acids	66.44	87.15	88.2

Role of *Saccharomyces cerevisiae* in animals feed

Saccharomyces cerevisiae is one of the microbes that have been implicated on food safety.[13,48] *Saccharomyces cerevisiae* is not only useful in human diets but also in animal feed. As such it also has useful role in animal diets .[56–58] Llopis et al.[59] reported that *Saccharomyces cerevisiae* are essential for good health because of its intrinsic nutritional quality and bio-functional characteristics. Probably due to these, it has been widely studied in animal especially domesticated ones such as cattle, goats, sheep etc, and other livestock's such as poultry (birds). Stercova et al.[60] reported that live cultures of *Saccharomyces cerevisiae* on animal diet could enhance the role of beneficial digestive microflora and suppress the growth of pathogens, thereby contributing to the improvement of performance. This section highlights the specific roles of *Saccharomyces cerevisiae* in animal diets, growth and productivity.

Nutrient digestibility

Saccharomyces cerevisiae have been variously reported to play essential role in nutrient digestibility in animals. Abd El-Tabawab et al.[61] reported that probiotics improves nutrient digestibility and feed conversion rate among ruminant animals. Stercova et al.[60] studied the role of live *Saccharomyces cerevisiae* on nutrient digestibility and fecal microflora using dogs as experimental animal and reported an improvement in the neutral detergent fiber. Khadem et al.[62] studied the effects of live yeast *Saccharomyces cerevisiae* (strain *Sc* 47) on rumen fermentation, microbial populations, nutrient, digestibility, alfalfa degradability and performances of sheep and results showed that 2.5g of organisms per sheep/day could enhance ruminal fermentation and superior performances in Chall sheep. According to Sontakke[49] , live yeast in diet of ruminant animals could enhance digestibility and absorption of minerals (viz: phosphorus, magnesium, calcium, copper, potassium, zinc and manganese), consumption of dry matter, utilization of fibre and other nutritive substances.

Adsorption of toxic metal

Heavy metals are known to be toxic at certain concentration for the essential ones, while the non-essential metals are highly toxic even at low concentrations.[63–67] Microbes such as *Saccharomyces cerevisiae* have the tendency to remove heavy metals through biosorption.[20] Furthermore, El-Moneim et al.[68] reported that *Saccharomyces cerevisiae* is a strong probiotic agent that could detoxify cadmium in food, thereby reducing the harmful effect of its toxicity in animal diets.

Weaning potentials

Weaning is one of the most important stress periods in pig farming industry, and it deeply affects gut health and the immune system.[69] The authors further reported that weaning could result in the decline feed intake among ruminant animal such as piglets that have serious health effects such as diarrhea and dysfunction of the immune system. Trckova et al.[57] reported that dietary supplementation with live *Saccharomyces cerevisiae* in diets of sows and piglets in the late gestation, suckling, and postweaning periods could lead to reduction in the duration and severity of postweaning diarrhea caused by enterotoxigenic *Escherichia coli*. Abd El-Tabawab et al.[61] reported that *Saccharomyces cerevisiae* in ruminant could lead to reduction in neonatal diarrhea and mortality. Bruno et al.[58] reported that dairy cow diets supplemented with yeast culture enhance lactation performance by increasing yields of milk when exposed to heat stress condition.

Milk production

According to Al – Jassem et al.[70], milk is an essential nutrient that contains several vital nutrients required for growth. Typically, the udder is one of the vital areas in ruminant that are affected by infection. Therefore, milk production is influenced by infection level. Dead bacteria could cause toxin that predispose the ruminant animals to inflammation of the udder. But several microbes such as *Saccharomyces cerevisiae* play essential role in milk production among ruminant animals. AbdEl-Tabawab et al.[61] stated that *Saccharomyces cerevisiae* enhance milk production in ruminant animals. Al – Jassem et al.[70] reported that *Saccharomyces cerevisiae* could boost milk production in Crossbred Holstein Cows. Zhu et al.[71] also reported that *Saccharomyces cerevisiae* in cow diet could aid in the effective maintenance of milk during mid-lactation period. Yalçın et al.[72] reported that live *Saccharomyces cerevisiae* can improve the nutritional value, milk production and its quality in cow.

Performance

The use of probiotics has showed to confer and improve productivity/performance.[61] Several substrates have demonstrated potential for utilization in animal feed. Some of them have reported to boost performance in livestock's. Liu et al.[69] reported *Saccharomyces cerevisiae* cell wall extract supplemented to feed could improve growth performance, concentration of some essential amino acids, and alleviate oxidative stress in weaning piglets. Kiros et al.[73] reported that live *Saccharomyces cerevisiae* could boost performance and hindgut microbiota composition (especially *Coriobacteriaceae, Ruminococcaceae, Clostridiaceae, Peptostreptococcaceae*, and *Peptococcaceae*) of weaning pigs. Scott et al.[74] reported that *Saccharomyces cerevisiae* in diets of heifers could improve growth performance, carcass characteristics, and reduce liver abscess. Aghdamshahriar et al.[75] reported that *Saccharomyces cerevisiae* in fish meal and poultry by-product protein can enhance performance in broilers and its meat quality.

Immunity

Animals general possess a primitive defense against the pathogens that they may be susceptible to. Most animals have innate or natural immunity that help them wade off some diseases causing pathogens. On the other hand, some microbes have the tendency to protect an animal against low immunity. Specifically, *Saccharomyces cerevisiae* has the tendency to confer immunity in ruminant animals.[61] Luquetti et al.[76] reported that 0.2% supplementation of *Saccharomyces cerevisiae* in cell wall is capable of protecting the intestinal mucosa of broiler chickens vaccinated against coccidiosis.

Rumen maturity and stabilization

With the restriction in the use of antibiotics in livestock, studies in the use of botanicals and microbes as additives in feed have increased. The use of probiotics has showed to enhance rumen microbial ecosystem and good health among animals.[61] Several factors lead to imbalance in flora population in young ruminant animals and they are more prone to infection. Several microbes play essential role in rumen of ruminant animals. Sontakke[49] reported that *Saccharomyces cerevisiae* enhance the population and stability of cellulolytic rumen microbes. Kowalik et al.[77] reported that *Saccharomyces cerevisiae* in diet of heifer increase rumen fluid pH, molar concentration of acetate and acetate to propionate ratio, but decrease molar proportions of propionate and butyrate, total protein, triacylglycerol and total cholesterol concentrations. Zhu et al.[71] reported that *Saccharomyces cerevisiae* fermentation products (corn stover) improved cow rumen function causing the microbial density to shift toward greater rumen fermentation efficiency which is characterized by high rumen fungi and cellulolytic bacteria and low lactate producing bacteria; production of high energy and protein which are indicated by greater ruminal volatile fatty acid concentration; and an enhanced nitrogen conversion. Doležalet al.[56] reported that *Saccharomyces cerevisiae* (SC-47) has positive effect on ruminal digestion in dairy cows of Holstein breed especially with regard to pH and volatile fatty acids. Authors have also reported that *Saccharomyces cerevisiae* are known to stabilize the pH of the rumen.[49,61]

Fiber degradation

Yeast species including *Saccharomyces cerevisiae* that are used as probiotic has the tendency to enhance the growth and activities of fibre-degrading microorganisms.[49] Typically, rumen of animals can be considered as anaerobic condition but dissolved oxygen can be traced to the rumen through feed and water intake as well as salivation.[49] As such, yeast cell have the tendency to scavenge for oxygen.[49] Cömert et al.[78] reported *Saccharomyces cerevisiae* supplementation and anhydrous ammonia treatment of wheat straw improves degradability, weight gain etc.

Conclusion and the way forward

Palm oil and cassava mill effluents cause an alteration in receiving environment (soil and surface water). Studies have shown that microbes such as *Saccharomyces cerevisiae* has the tendency to reduce the pollution associated with both effluents while generating biomass. The biomass generated from both effluents is of low yield which is approximately 4.00g/L. The biomass cultured in both effluents has shown to contain appreciable amount of protein and essential amino acid. Specifically, *Saccharomyces cerevisiae* biomass grown in cassava mill effluents contains some essential heavy metals, low in cyanide and appreciable amount of cations (calcium, magnesium, sodium and potassium). Hence, utilization of both effluents to grow *Saccharomyces cerevisiae* biomass for possible use in animal feed industry will reduce the attendant environmental impacts associated with the effluents while minimizing cost of conventional feeds. Due to the potentials of Saccharomyces cerevisiae biomass from both effluents to be utilized in animal feed, there is the need for research to focus on techniques through which the biomass produced could be enhanced. Evaluation of other nutrient determinant such as vitamins, and possiblely assessing the effectiveness of the biomass in animal diets with regard to digestibility, milk production, immunity conferment, rumen microflora and pH stabilization, overall performance etc.

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Conflict of interest

The author declares there is no conflict of interest.

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