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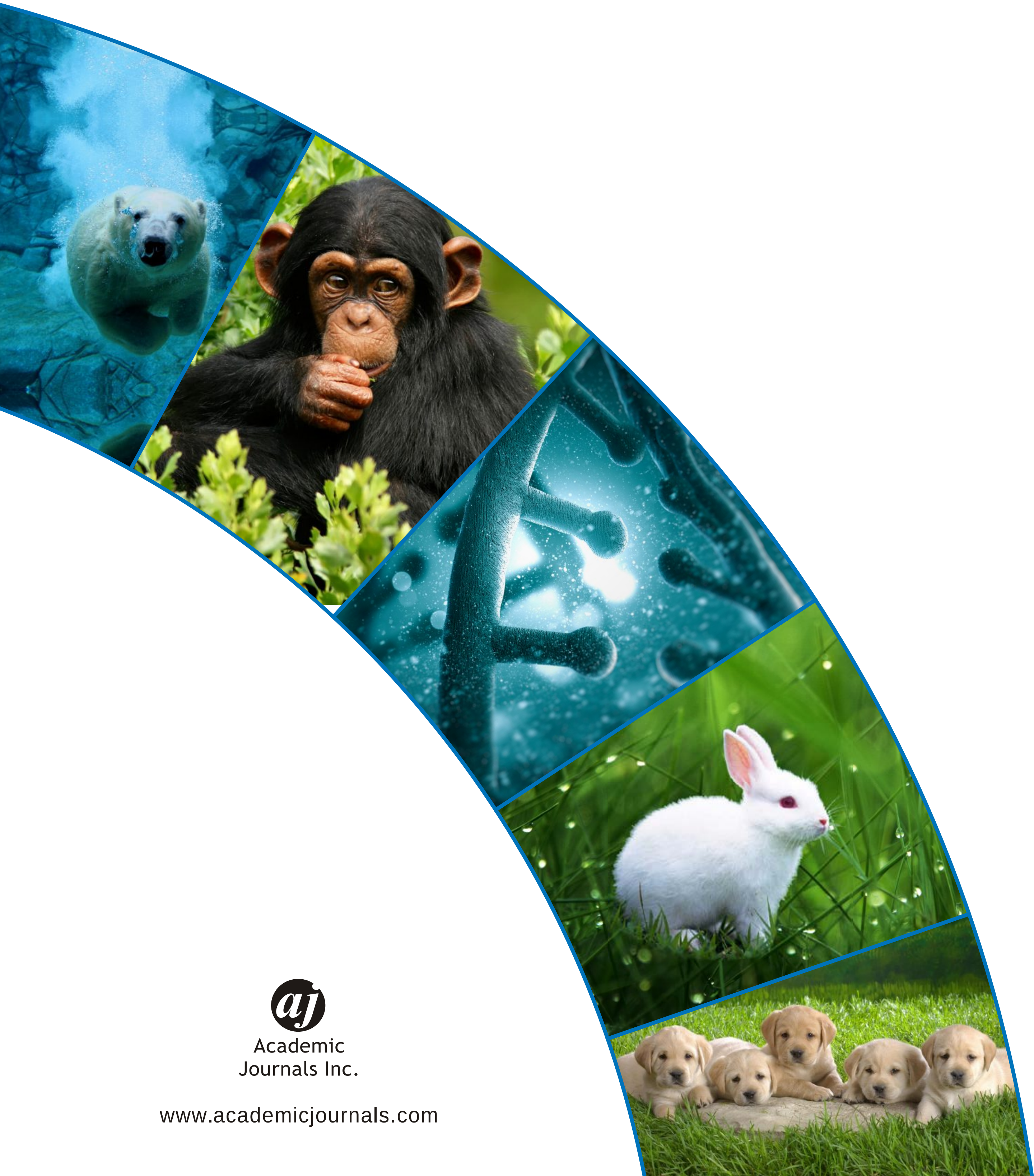
Asian Journal of Animal and Veterinary Advances



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OPEN ACCESS Asian Journal of Animal and Veterinary Advances
ISSN 1683-9919
DOI: 10.3923/ajava.2023.44.56

Review Article
Potentials of Palm Wine as Probiotics and Organic Acids Source in Animal Nutrition

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Abstract
Feed is the most critical factor in animal production and the availability of cheap and high-quality feeds are crucial to sustainable livestock production. With the persistent scarcity and high cost of core feed inputs, the use of additives to increase feed use and economic efficiency through improved animal health and performance has gained popularity over the years. In recent times, non-antibiotic feed supplements, such as prebiotics, probiotics, enzymes, herbal mixtures and clay minerals have been tested as effective feed additives in animal diets. Organic acids and probiotic products are dietary feed additives with growth-promoting abilities similar to antibiotics. However, palm sap, an alcoholic beverage from various palm species has shown promise as a potential source of organic acids and direct-fed microbial products. Thus, this review provides a brief discussion on the microbial and biochemical characteristics of palm wine and its potential benefits to the livestock industry to improve performance, increased digestive efficiency, reduce the proliferation of pathogenic organisms and disease incidence in animal production. From the kinds of literature reviewed, it can be concluded that the metabolic products of palm wine fermentation had bacteriostatic and bactericidal properties to inhibit pathogens while improving the growth performance of animals.

Key words: Palm wine, nutrient composition, probiotics, organic acids, growth-promoting additive

Citation: Ohanaka, A.U.C., J.N. Ohanaka, N.O. Aladi, I.P. Ogbuewu, I.F. Etuk and I.C. Okoli, 2023. Potentials of palm wine as probiotics and organic acids source in animal nutrition. Asian J. Anim. Vet. Adv., 18: 44-56.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The intensification of livestock production has necessitated the use of additives to improve the productive performance of farm animals and has become a common practice in the industry. Additives are generally referred to as substances or preparations that are intentionally added to animal feed to improve productive, reproductive and health performances in animals[1].

For years, animal feeds were routinely formulated with antibiotic additives to achieve a high level of economic efficiency in livestock production through increased feed utilization and gut modifications[2,3]. However, with the complete ban of in-feed antimicrobials in food animal production and products in Europe and America[4], due to increased cases of antibiotic resistance[5,6] and residual antibiotic concentrations in meat[7,8], the provision of cost-effective alternatives that will maintain the health and performance of food animals becomes paramount[9-11]. Several additives with antimicrobial properties have been suggested as alternatives to antibiotics in animal production. Common examples include enzymes, organic acids, prebiotics, probiotics, antioxidants, vitamins, minerals, amino acids, activated charcoal and binder's etc.[12-14]. These products have been shown to improve the growth performance, health and overall wellbeing of animals through a complex interaction between the animal's diets, its gut and microbiota[11,15-18].

Probiotics and organic acids for example are non-antibiotic growth-promoting feed additives directly fed to animals to favourably influence host intestinal microbiota and immune system functions[14,19-21]. Probiotics are live organisms like the *Lactobacilli* spp., *Saccharomyces cerevisiae*, *Bacillus* spp., *Bifidobacteria* spp., etc., supplemented in animal feeds to improve performance and health status of treated animals through gut modifications, improved nutrient absorption[22,23] and digestive enzymes secretions[24-26]. Studies have reported improved digestion and utilization of nutrients, egg production and modulation of immune system function in poultry fed dietary probiotics[27-30].

Similarly, organic acids or acidifiers such as acetic, lactic, butyric, propionic acids etc., have been supplemented in animal feeds because of their various beneficial effects in feed preservation from spoilage organisms, improved nutrient absorption, inhibition of gut pathogenic bacteria proliferation and promotion of healthy gut microbiota[31-34]. These acids which are sometimes produced through microbial degradation of fermentative products in the intestine have acidic and bacteriostatic properties and therefore can decrease the gut pH and colonization by pathogenic microbes[14,35-37]. The dietary inclusion of organic acid in feeds reportedly increases weight gain and better feed to gain ratio in broilers[38,39] and pigs[40-42]. Improved egg-laying and eggshell quality in the hen has also been associated with the feeding of organic acids[43-45]. The ability of acidifiers to influence gut morphology and increased intestinal nutrient transport has also been reported[46-48].

Therefore, the manipulation of animal diets using probiotic and organic acid supplements singly or in combination will improve growth performance through improved feed utilization, nutrient digestibility and a healthy gut microbiome[49,50], while unfavourable microbiota may promote enteric infections leading to decreased growth and increased mortality[22,51].

Palm wine could be a source of probiotics and an organic source for livestock improvement. Palm wine is a fermented alcoholic beverage produced by the natural fermentation of the milky sap obtained from various tropical palm trees[52]. Common examples include raffia palm (*Raphia hookeri*)[53,54], oil palm (*Elaeis guineensis*)[55,56], date palm (*Phoenix dactylifera*)[57,58], coconut palm (*Cocos nucifera*)[59,60], nipa palm (*Nypa fruticans*)[61,62] and ron palm[63,64].

In Nigeria, raphia palm and oil palm are the two major sources of palm sap[65]. The sap is consumed widely in most of West Africa and other regions of the world mostly for its rich content of sugar molecules, proteins, alcohol, organic acids, minerals, vitamins and direct-fed microbial products (yeast, lactic acid-forming bacteria (LAB) and acetic acid-forming bacteria (AAB) etc.), that have been identified for their probiotic potentials[60,64,66,67]. The sap has been reported to contain high concentrations of sugar molecules capable of sustaining weight gain and profitability in indigenous pigs around Southeast Asia[68,69].

This paper attempted to highlight the potential benefits of palm wine as a nutritive and probiotic source to maintain gut health and increase the performance of food animal production.

Sources and microbial characteristics of palm wine: The rich microbial diversity present in palm wine was highlighted in Table 1. The community of microbes contained in the sap is largely populated by yeasts, LAB and AABs amongst other microbes[56,60,64,67,70] as highlighted in Table 1. These organisms were either indigenous in the inflorescence of the palm trees[64,67] or introduced into the wine through the activities of the wine tapper using his implements (tapping knives, funnels and collecting gourds) and/or invading insects during wine tapping[55,71]. The presence of these micro-organisms in the sap plays a fundamental role in wine fermentation by initiating

Table 1: Microbial content of palm wine

Microbial diversity	Examples	References
Yeast	*Saccharomyces* spp., *Saccharomycodes* spp., *Schizosaccharomyces* spp., *Pichia* spp., *Hanseniaspora* spp. and *Candida* spp.	Abayomi *et al.*[56], Djeni *et al.*[64], Obi *et al.*[79], Trevanich *et al.*[80] and Onwumah *et al.*[81]
LAB	*Lactobacillus* spp., *Leuconostoc* spp., *Fructobacillus* spp. and *Lactococcus* spp.	Diaz *et al.*[59], Astudillo-Melgar *et al.*[60], Djeni *et al.*[64], Kouamé *et al.*[70], Adamu-Governor *et al.*[82] and Akinrotoye[83]
	Lactobacillus spp., *Bacillus* spp., *Streptococcus* spp. and *Enterococcus* spp.	Nkemnaso and Lois[53] and Obi *et al.*[79]
AAB	*Acetobacter* spp., *Gluconacetobacter* spp. and *Gluconobacter* spp.	Astudillo-Melgar *et al.*[60], Ouoba *et al.*[63], Djeni *et al.*[64] and Kadere *et al.*[84]
Others	*Staphylococcus aureus*, *E. coli*, *Micrococcus luteus*, *Serratia* spp., *Proteus bulgaricus*, *Pseudomonas aeruginosa*, *Micrococcus luteus*, *Zymomonas* spp. and *Sarcina* spp.	Djeni *et al.*[64], Obi *et al.*[79] and Akinrotoye[83]
	Vibrio spp., *Sphingomonas* spp., *Erwinia* spp., *Klebsiella* spp., *Serratia* spp. and *Cronobacter*	Astudillo-Melgar *et al.*[60]

rapid degradation of its rich sugar reserves into several metabolites which significantly alter the physico-chemical constituents and microbial composition of the wine produced. The presence of yeast, particularly *Saccharomyces cerevisiae* has been identified as the most dominant yeast species responsible for the alcoholic content of palm wine[55,64,72]. Studies have also identified *Saccharomyces chevalieri* to predominate other yeast species in ‘Toddy drink’, a locally brewed wine from the coconut palm, whose activity with *Zymomonas mobilis* were reported responsible for the increased alcoholic concentration of fermenting wine[73]. The presence of non-*Saccharomyces* yeast such as *Pichia* spp., *Candida* spp., *Hanseniaspora* spp., *Saccharomycopsis* spp., *Saccharomycodes* spp. and *Endomycopsis* spp., have been observed in palm wine[54,64,74,75].

A wide range of LAB, AAB and non-yeast forming bacteria (Table 1) have also been isolated from different palm wine sources at various stages of fermentation[47,55,59,67]. For example, Astudillo-Melgar *et al.*[60] identified LABs of *Fructobacillus*, *Leuconostoc* and *Lactococcus* spp., AABs of *Gluconacetobacter* and *Acetobacter* spp. and a Proteobacteria (*Vibrio*) to predominate the ‘Tuba’ wine, a local brew from coconut (*Cocos nucifera*) tree sap. Djeni *et al.*[64] identified *Lactobacillus* and *Leuconostoc* spp., AABs of *Acetobacter*, *Gluconacetobacter* and *Gluconobacter* spp. and non-yeast forming microbes (*Sphingomonas* and *Enterobacteria* spp.), to predominate wine samples of oil palm, raphia palm and ron palm produced in Côte d'Ivoire.

However, the diversity and succession of these live organisms in palm wine are largely influenced by the specie of palm tree, the sap composition, stages of sap fermentation and certain bio-physical conditions like the season of tapping (whether rainy or dry season), age of palm tree, soil conditions and other environmental factors[76,77]. For example, there seem to be more *Lactobacillus* spp., bacteria in ron and *Elaeis* palm wine than could be found in raphia wines, while *Leuconostoc mesenteroides* was abundantly present in *Raphia* sap.[64].

Coconut palm wine (Tuba) brewed in Mexico is heavily dominated by *Fructobacillus* and *Gluconacetobacter* compared to other LAB and acetic acid bacteria[59,60]. The ‘Bandji’ drink locally brewed in Burkina Faso from palm wine of *Borassus akeassii* (ron palm) has *Acetobacter indonesiensis* as the predominant AAB compared to other AAB spps.[63].

More importantly, the ageing of wine as a result of fermentation during storage affects significantly the bacteria sequence in the wine. For instance, Stringini *et al.*[78] had reported the disappearance of certain yeast and non-yeast forming bacteria in palm wine after 72 hrs of fermentation, while *Saccharomyces cerevisiae* remained dominant all through the fermentative process. Similar observations have since been reported in palm wines with increased fermentation time[53,60,79]. The gradual decrease or annihilation of these microbes (mostly pathogenic) with increased fermentation was associated with the increased acidification and decreasing pH of the fermenting. Palm wine resulting from the activities of LABs and AAB spps.[85].

According to reports, *Acetobacter* spps., were more pronounced in palm wine after 72 hrs of fermentation, at which time the substantial quantity of alcohol has been produced as the appropriate substrate for acetic acid production by AAB[86,87]. The activities of LAB and AAB species and their associated metabolic products have shown great promises in providing productive performance and health benefits in treated animals[88-91]. It is still possible that the application of fermented wine or its microbial products in animal feed will evoke favourable responses in fed animals similar to common probiotic and organic acid products through improved gut health and digestive efficiency.

Nutrient composition and chemical characteristics of palm wine: The nutrient composition and chemistry of palm wine is presented in Table 2. Freshly tapped palm wine sap is a clear, colourless and sweet syrup largely composed of nutritional and chemical components such as sugars and various concentrations of proteins, alcohol, vitamins and

Table 2: Nutrient composition of palm wine

Products	Examples	References
Sugars	Sucrose, Glucose and Fructose	Astudillo-Melgar *et al.*[60], Amoa-Awua *et al.*[85], Zongo *et al.*[97] and Makhlouf-Gafsi *et al.*[109]
	Maltose, Xylose, Rhamnose, Arabinose and Cellobiose	Santiago-Urbina *et al.*[52], Nwaiwu *et al.*[55], and Shetty *et al.*[95]
	Galacturonate, UDP-D-xylose, UDP-L-arabinose, UDP-D-Galacturonate, deoxy hexose sugars and Myo-inositol	Djeni *et al.*[64]
	5-keto-D-fructose, Ethyl-1-thio-alpha-D-arabinofuranoside and D-methyl-1-fucose	Erukainure *et al.*[54]
	D-tagatose, β-N-acetyl glucosamine, allose and galactitol	Erukainure *et al.*[98]
Alcohol	Ethanol, Butanol, 1-propanol, Isopentylalcohol, 3-methylbutanol and 2-phenylethanol	Nwaiwu *et al.*[55] and Lasekan *et al.*[94]
	Glycerol and 1-deoxy-D-arabitol	Erukainure *et al.*[54]
Esters	Methylpropyl lactate, Ethyl acetate, Methyl cinnamate, Ethyl hexanoate, Ethyl lactate, Methylpropyl acetate, Methyl-2-methyl propanoate, Ethyl dodecanoate, Ethyl octanoate, Diethyl succinate, methyl butanoate and 3-isobutyl-2-methoxypyrazine	Nwaiwu *et al.*[55], Lasekan *et al.*[94] and Uzochukwu *et al.*[105]
Organic acids	Lactic acid, Acetic acid, Propanoic, Hexanoic and Oleic	Nwaiwu *et al.*[55]
	Lactic acid, Acetic acid, Tartaric, Oxalic, Citric, Malic, Fumaric, Pyruvic acid, Succinic acid and Ascorbic acids	Karamoko *et al.*[99]
	Pentanoic acid, Nonadecanoic acid, Dodecanoic, Tetradecanoic, Quinic, Palmitoleic acid, Octadecanoic acid and 2-hydroxyoctanoic acid	Erukainure *et al.*[54]
Protein and amino acids	Methionine, Lysine, Tryptophan, Leucine, Isoleucine, Arginine, Phenylalanine, Cystine, Aspartic acid, Glutamic acid, Serine, Asparagines, Citrulline, Alanine, Tyrosine, Amino-butyric acid, Valine, Glycine and Proline	Ibegbulem *et al.*[108], Makhlouf-Gafsi *et al.*[109] and Okafor[110]
Minerals and vitamins	Mg, P, Cu, Fe, Mn, Pb, Cd, Co, Zn, Ca and Ammonia	Thabet *et al.*[57], Ogbonna *et al.*[92], Zongo *et al.*[97] and David *et al.*[111]
	Vitamin A, vitamin C, vitamin B1 and C, vitamin B6 and pyrimidine, vitamin B12	Erukainure *et al.*[54], Ogbonna *et al.*[92], Ezeagu *et al.*[93], Ibegbulem *et al.*[108]

minerals[67,92]. The clear sap has a near-neutral (7-7.4) pH[74,93,94], which progressively decreases with increased fermentation of the sap which ultimately alters the original colour of the sap to a milky white hue. Reports suggest that the resulting colour change was a result of the production of dextran by the lactic acid bacteria during fermentation[95,96].

Sugars: Several studies have highlighted the nutritive potential of palm sap to contain a rich suspension of sugar molecules predominantly sucrose, glucose, fructose and maltose sugars[60,64,66,97]. According to reports, sucrose is the most abundant sugar in freshly tapped palm sap. It also contains traces of other sugar molecules such as xylose, cellobiose, galacturonic acid, arabinose, lactose, rhamnose, d-tagatose and allose etc.[52,55,95,98]. As the palm sap ages, it undergoes spontaneous fermentation, which promotes the proliferation of microbial organisms whose activities have been identified to significantly alter the biochemical and microbiological properties of the sap. Firstly, the rich sugars are rapidly broken down into several metabolites, mainly ethanol, lactic acid and acetic acid, thereby increasing the acidity of the palm sap with the consequent pH reductions (4.5-2.8)[60,66,85].

Alcohols: The increased acidity of the during fermentation sap has been reported to enhance the invertase enzyme activities of yeast and LAB organisms that catalyses the hydrolysis of sucrose to glucose and fructose, which are known substrates/precursors for ethanol production[66,95]. This results in the radical increase in the alcoholic content of the sap as fermentation progresses towards 5-7 days, after which it declines due to the build-up of acetic acid[52,85]. At this stage, the AAB utilizes the high alcohol concentration as a substrate for acetic acid production.

Organic acids: Lactic acid has been reported as the main acid responsible for the acidification of aged-palm wine as it undergoes fermentative organic acid production[63,66,67]. Acetic and tartaric acids have also been shown to increase the acidity of palm wine with prolonged fermentation. However, traces of other organic acids such oxalic, citric, malic, lactate, fumaric, pyruvic acid, propionate, succinic acid and ascorbic acids were found present in fermented palm wine[96-99]. These acids have been recognized for their inhibitory effect on pathogenic organisms, especially on the members of *Enterobacteriaceae*[100-102].

Colourants, odorants and flavour ants: Another consequence of the sustained fermentative process in palm wine is the dramatic change in colour, gas evolution and the formation of various flavour components that affects its organoleptic properties[103,104]. Volatile compounds such as esters, carboxylic acids, fatty acids, acyloin, etc., in Table 2 are reportedly contained in fermented palm wine thereby conferring the characteristic aroma and taste of the wine[55,105,106]. Esters are however the dominant compounds among the group. A good example is the ethyl acetate reported for its dominant aroma, while ethyl lactate influences more of palm wine flavour[55]. Ethyl acetate is formed by the combination of ethanol and acetic acid during fermentation in palm wine[105,107]. Other potent odorants identified in palm wine include ethyl pentanoate, 2-phenyl ethanol, 3-isobutyl-2-methoxypyrazine, acetoin, ethyl lactate, ethyl-hexanoate, 3-methyl-butyl acetate, butyl acetate, 2-acetyl-1-pyrroline, propyl acetate, methyl cinnamate and butanol etc.[55,94].

Proteins and amino acids: The palm wine has been observed to contain some concentrations of protein and amino acids. Both essential and non-essential amino acids such as methionine, lysine, tryptophan, leucine, isoleucine, arginine, phenylalanine, cysteine, aspartic acid, glutamic acid, serine, asparagines, citrulline, alanine, tyrosine, amino-butyric acid, valine, glycine and proline have all been identified in palm sap and fermented wine[108,109]. However, the fermentation process of the sap was reported to modify the amino acid profile of the palm sap[110].

Vitamins and minerals: Palm sap has also been reported to contain some levels of macro and micro mineral elements (Table 2) as well as essential vitamins[57,93,97,111]. Ezeagu *et al.*[93] reported that magnesium and phosphorus were the chief minerals present in oil palm sap with some traces of lead, cadmium and cobalt. Copper, iron, zinc, manganese and calcium were also present in lower concentrations. Thabet *et al.*[57] reported potassium as the most abundant mineral fraction in *Phoenix dactylifera* palm sap, followed by magnesium and phosphorus. The authors also recorded other minerals fractions in the sap in decreasing order of concentration such as Ca, Na, Fe, Cu and Zn.

Essential vitamins such as vitamin A, B complex and C have been reportedly contained in freshly tapped palm sap. The B complex vitamins like the B1, B2, B6 and B12, concentrations in palm wine were influenced and increased in their concentration over 7 days of the fermentative process while the vitamin C concentration declined within the initial 24 hrs of sap fermentation[110]. Dietary minerals and vitamins are important nutrients and have been associated with optimum performance and immune responses in supplemented animals. They have been reported to induce appetite, increase nutrient digestibility, support blood formation while regulating gut ecology.

Studies also suggested that the biochemical constituents of palm wine were influenced by other variables such as the species of palm tree tapped[67,108], tapping process (frequency of tapping, length of storage and collection time)[71,99], tapping season and environment factors[112]. Reports have shown for example, that the sugar concentrations of palm sap were much higher during the early tapping stages but gradually declined with the progressive increase in tapping length and storage time due to the microbial fermentation of sugar molecules to produce alcohol[52,99]. According to Okafor[110], the pH, sucrose and vitamin C concentrations in palm wine decreased with increased tapping length, while other constituents such as ethyl alcohol, Titratable acidity, total nitrogen and vitamins B_1 and B_2, increased with tapping length. A much later study had reported more sucrose, glucose, fructose and maltose concentrations in *Raphia hookeri* wine samples on the first day of tapping than xylose, cellobiose, galacturonic acid, arabinose and rhamnose sugars[52]. Seasonal changes in wine characteristics have also been reported[85,110]. Observed the alcohol content of palm wine to be more prominent during the rainy season compared with the dry season, while wine collected during the day had less alcohol than that accumulated over the night.

Palm wine as sources of probiotics and organic acids in animal production: Palm wine from different sources has been widely studied for its potential benefits to man and animals alike due to its rich nutrient content (sugars, amino acids and proteins, vitamins, minerals) and heavy concentration of live micro-organisms particularly yeast, LAB and AAB[64,67]. These organisms have been implicated for their role in sugar fermentation, organic acid production and probiotic properties.

The dietary supplementation of probiotics and organic acids in feeds have gained popularity as a growth-promoting agent in livestock production[113-115] and thus produces antimicrobial substances that can successfully colonize the gut and maintain intestinal microbial balance[114,116].

The majority of probiotics belong to the LAB[117-119]. The dietary supplementation of LABs in the diets of laying hen increased egg-laying performance, egg quality and eggshell characteristics in treated hen[120,121]. Significant improvements in body weight, digestive efficiency and intestinal integrity, have been reported in broilers and piglets fed diets supplemented with LABs or their metabolites[25,26,122].

Palm wine and its associated products have shown great promises as non-antibiotic performance-enhancement feed additives in poultry production[123,124]. Palm wine-derived

Zymomonas mobilis enhanced the feeding value of fibrous agro-industrial by-products as alternative feed resources without any deleterious effect in broilers[125]. On-going work by the authors had observed that a blend of activated charcoal and aged palm wine (ACAPS) increased egg-laying performance, ovarian weight development and decreased weight loss due to egg-laying in treated hens compared to the control. Similar observations of improved fertility and litter size were also reported in Wistar rats fed freshly-tapped palm wine[126]. Smallholder pig farmers in Cambodia found the feeding of pigs with *Borassus flabellifer* palm sap improved body weight in pigs and was of more economic benefits to the farmers compared to its use in sugarproduction[68,69]. The improved performance resulting from palm wine feeding may be linked with the up regulation of enzymes that enhance feed digestibility and nutrient metabolism. The lactic acid-producing bacteria isolate from *Borassus* palm wine enhanced digestive enzyme (amylase) activities *in vitro*[127]. Similar findings by Sulistiani[128] also reported enzymatic activities (amylase, protease and phytase) by LAB strains isolated from *Borassus flabellifer* palm wine. Reports have shown that LABs exhibiting enzymatic activities improved growth performance[129,130] and enhanced nutrient digestion, especially in newly hatched chicks[131,132]. The production of the beta-galactosidase enzyme in high amounts enhanced lactose digestion[133,134], while the bile salt hydrolase (BSH) enzyme reduced serum cholesterol through increased synthesis of bile salts from serum cholesterol and decreased uptake from the gut[135]. *In vivo* and *in vitro* studies by Ngongang *et al.*[136] reported significant reductions of serum total cholesterol, triglycerides, Very Low Density Lipoprotein (VLDL) and Low Density Lipoprotein (LDL) by *Lactobacillus* spps., isolated from *Raphia mambillensis* palm wine but increased High Density Lipoprotein (HDL) levels when administered in a rat model. Another study by Tranto *et al.*[137] also demonstrated the hypocholesterolemic effect of *Lactobacillus reuterin* supplementation. *Lactobacillus reuterin* produces reuter in as a secondary metabolite associated with glycerol metabolism and has shown inhibitory activities against pathogens like *E. coli*, *Candida* and *Staphylococcus* spps.[138]. Reports have also highlighted the anti-oxidative and anti-diabetic properties of palm wine in challenged rat model[54,98].

Another benefit derivable from palm wine in livestock production is its gut health-promoting effect through gastrointestinal tract (GIT) reductions of pathogenic organisms. Yeast isolates from palm wine have shown strong antimicrobial activities against pathogenic organisms such as *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Klebsiella* spps.[139,140]. A study by Ojo and Agboola[141], observed that fermented palm wine of *Raphia vinifera* and *Elaeis guineensis* had an inhibitory effect against *Salmonella typhi* compared to antibiotic drugs like chloramphenicol, amoxicillin, Gentamicin and ciprofloxacin. Similar inhibitory responses had been reported against diarrhoeagenic pathogens such as *Salmonella typhi*, *Shigella dysentariae*, *Staphylococcus aureus* and *E. coli*, compared to known antibiotics using a 7-day old fermented *Raphia* wine[83]. The responses observed may not be unconnected with the increased concentrations of metabolic products of wine fermentation such as lactic acid, acetic acid, alcohol, fatty acids and antimicrobial substances (bacteriocin, reutericyclin, mitoxantrone) known for their anti-microbial, immune-modulatory, anti-diabetic, anti-cancer, and cardio-circulatory functions[32,64,80,139,142,143]. The production of short-chain fatty acids particularly lactic and acetic acid by the LABs and AABs induces an unfavourable micro-environment inimical to the survival of intestinal pathogens through gut pH reductions[144,145]. According to Wang *et al.*[146], 0.5% lactic acid concentrations completely inhibited the growth of important pathogens like *Salmonella* spp., *E. coli* or *Listeria monocytogenes*. A similar response had been observed with dietary feeding of acetic acid product from fermented palm wine in poultry[147]. The production of bacteriocin by lactic acid-producing bacteria has shown bactericidal or bacteriostatic activities against bacteria pathogens[148,149]. Bacteriocins are known antimicrobial peptides produced by bacteria whose activities selectively inhibit the proliferation of bacteria other than the producing strain[18,150].

Recent studies have demonstrated successfully the production of bacteriocin from LAB isolates of palm wine origin with inhibitory effects against pathogens. For example, Fossi *et al.*[151] identified bacteriocins from 3 LAB strains (*Lactobacillus plantarum*, *L. rhamnose* and *L. brevis*) from palm wines (*Elaeis guineensis* and *Raphia sudanica*) with inhibitory effect against *Salmonella typhimurium, Staphylococcus aureus* and *Listeria monocytogenes*. Tongwa *et al.*[152] isolated Lactobacillus species from *Raphia mambillensis* palm wine with strong inhibition against important pathogenic microbes including *E. coli*, *Salmonella* spps. and *Staphylococcus aureus*. *In vitro* studies using *Lactobacillus rhamnosus* (IS9) isolated from palm wine strongly inhibited the growth of several strains of *Salmonella enteritidis* just like any other antibiotic[153]. The authors also reported significant reductions of *Salmonella* count in the GIT of young chicks pre-dosed with *Salmonella enteritidis* and *typhimurium*, respectively using palm wine-derived LABs. The bacteriocin-producing LAB species locally brewed from palm wine inhibited a wide range of pathogenic bacteria *in vitro*[143,154]. Sulistiani[128] also reported significant antibacterial activity against important pathogenic bacteria such as *Escherichia coli*, *Pseudomonas aeruginosa*, *Listeria monocytogenes*, *Bacillus subtilis*, *Staphylococcus aureus* and *Salmonella enteritidis* by LABs from *Borassus* palm wine. Palm wine derived *Lactobacilli* increased cell-mediated and innate immune responses in a rat model that were induced with a sheep red blood cell (SRBC) antigen[155]. The LAB strains also caused increased stimulation in numbers of leukocytes mobilized to the site of injury in the rat model. The feeding of dietary LAB and dextran not only caused an improved immune response in chicken[156] but also increased milk yield of Holstein[157].

CONCLUSION

In conclusion, the available literature review suggests that palm wine can be used as a probiotic and organic acid source to evoke performance responses of farm animals. It can also successfully inhibit the proliferation of pathogenic organisms in the GIT of animals and their metabolic side effects depending on the duration of fermentation. It can therefore be recommended as a performance-enhancing and health-promoting agent to increase productivity and profitability in animal production. Further studies are, however, required to understudy the influence of palm wine feeding on intestinal microbial ecology and gene expression in animal production.

SIGNIFICANCE STATEMENT

This study discovered that palm wine is a rich source of nutrients and fermentative products that can be beneficial in food animal production. The presence of antibiotic-like substances (bacteriocin, reutericyclin, organic acids, lactic acid and acetic bacteria) from the sap especially when fermented showed strong anti-microbial activity similar to known antibiotics against some enteric pathogens. This study will help the researchers to uncover the critical areas of using palm wine as a performance-enhancing additive which has not been explored by many researchers. Thus, a new theory on its application as a low-cost alternative to antibiotic growth promoters may be arrived at.

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