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REVIEW ARTICLE

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Prospect of yeast probiotic inclusion enhances livestock feeds utilization and performance: an overview

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Abstract

An important aspect of live yeast (*Saccharomyces cerevisiae*) inclusion in the diets of ruminants is improved animal productivity. Inclusion of yeasts in ruminant diets may alter rumen microbes and their metabolites and promote a favorable intestinal microflora by increasing the population of beneficial microorganisms. Beneficial microbes compete for nutrients and attachment sites with pathogens, thereby reducing the growth of harmful microbes in the rumen. Yeasts enhance growth and average daily weight gain of animals by improving nutrients digestion and absorption. Probiotics can alter the fatty acid composition of meat and milk, and it is common knowledge that a lower fatty acid profile may directly confer health benefits to consumers by reducing harmful cholesterol levels in animal products and thus favorable to human nutrition. Furthermore, yeast probiotics have been shown to enhance immunity by inducing an immunomodulatory effect on the animal in addition to their ability to lower cholesterol, adhesion properties of the intestinal mucosa, and colonial resistance to strengthen gut integrity. This review highlights that yeast probiotics play a role in the ruminal microbial population dynamics, cholesterol-lowering ability and immunostimulatory potentials, yeast adhesion properties, and colonial resistance. Additional benefits include a healthy gut with concomitant increase in animal productivity, nutrient digestion, and absorption and general animal welfare. Overall, yeast probiotics appear to be a viable alternative to the use of antibiotics to improve animal welfare.

Keywords Yeast · Microbial population · Cholesterol · Immunity · Performance

1 Introduction

The uncontrolled use of antibiotics as growth promoters in animal production contributed to the spread of antibiotic resistance in animals and a possible link to antibiotic resistance in humans. Because of the biosecurity threats to human and animal health from the use of antibiotics, the European Union banned the use of antibiotics as growth promoters and for prophylaxis purposes in 2006 [1]. This ban has compelled researchers to search for alternative strategies to prevent infectious diseases and promote animal growth, health, and welfare. Growth promoters such as probiotics have the potential to alter the gut microbial ecology, which could have an impact on lipid metabolism and, in turn, affect the quality of animal products. However, this has yet to be completely investigated. Although a specific mode of action for probiotics has yet to be identified, a variety of pathways have been hypothesized. Probiotics can alter microbial populations in the rumen or hindgut, alter fermentation patterns, increase nutrient flow to the small intestine, and improve

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meal digestibility [2]. According to some researchers, adding probiotics to livestock feeds can lower blood cholesterol levels by allowing bacteria to directly assimilate cholesterol compounds [3]. Therefore, probiotic supplementation could improve livestock performance by maintaining a healthy rumen, boosting the digestion of fibrous feeds in the rumen by improving nutrient intake, and resulting in a higher production of livestock products [4]. *Saccharomyces cerevisiae*, a yeast, is one of the most prominent natural growth promoters used in animal production [5, 6]. Yeast has been extensively studied for decades as prominent natural growth promoter to replace antibiotics in ruminant nutrition. The beneficial effect of yeast in ruminants may be due to the fact that some nutrients from yeast products can be used by rumen microbes to increase microbial mass and other effects on the overall health and performance of ruminants [7, 8]. Several mechanisms of action have been identified, and yeast has shown the potential to scavenge O_2 from the rumen, making ecosystem more suitable for rumen anaerobic microbial growth. It can also increase rumen cellulolytic activity and nutrient digestion, which is especially beneficial in high fiber diets. Yeasts are also known to modulate rumen pH and reduce the risk of acidosis by regulating both lactate generating and lactate utilizing bacteria. Peptides, vitamins, organic acids, and cofactors are abundant in *S. cerevisiae*, which may be utilized by rumen bacteria [4, 7, 8]. In recent years, the beneficial effects of ruminant dietary supplementation with probiotics and their metabolites on animal production have been explored. Probiotic supplementation has a number of advantages, including enhancing rumen pH, modulating the immunological response, controlling gut pathogens, and improving health and productivity [4]. Several studies have shown that adding yeasts or their products in animal feed imparts various health benefits that include inhibiting the growth of pathogens in the gut [9] by producing metabolites that stimulate the growth of beneficial microorganisms [4, 10]. The presence of mannan oligosaccharides (MOS) in yeast helps in feeding of “good bacteria” at the expense of undesirable bacteria [11]. Several authors have reported improved nutrient efficiency in animals with the inclusion of yeast in their diets [10, 12, 13]. The administration of yeast increased dry matter intake in calves [14], improved feed conversion efficiency and growth rate [15], and enhanced animal growth performance [9] and milk production in dairy cows [16]. Khan et al. [17] reported that yeast (*S. cerevisiae*) provided organic acids and vitamins that stimulated the growth of lactic acid utilizing bacteria as well as improved rumen metabolism via stabilization of rumen pH in the rumen. Yeast also increases the population of cellulolytic bacteria which competes with lactate-producing bacteria for substrates. It scavenges available oxygen and improves anaerobiosis which provides a conducive environment for the growth and multiplication of anaerobic bacteria in the rumen [18]. Xiao et al. [19] reported that *S. cerevisiae* supplementation improved ruminal morphology by increasing the rumen population of *Butyrivibrio* and decreasing the rumen population of *Prevotella* with a resultant effect of an increase on the molar proportion of butyrate. There are several documented reports highlighting the significant effect of yeast inclusion on increased animal productivity [20–23]. The addition of live yeast in finishing lambs resulted in a 9% increase in carcass yield [24]. Mikulec et al. [25] reported that lambs had similar performance data and cut-out yields when supplemented with *S. cerevisiae* at 0.5 or 1 g/day. Moreover, Kawas et al. [26] reported no difference in some carcass characteristics with yeast inclusion. In contrast, Titi et al. [27] reported an increase in several performance variables with yeast inclusion. Incorporation of *S. cerevisiae* at 5 g/animal/day in the diet of dairy cattle heifers increased the nutrient digestibility, average daily weight gain, and health performance of animals without any detrimental effect [9]. Yeast increased milk yield when evaluating the efficacy of three types of yeast in goats, ewes, and dairy cows [28–30]. Likewise, Mašek et al. [31] observed an increase in total milk yield and milk components when yeast was fed to lactating ewes. In contrast, AlZahal et al. [32] reported that supplementation of active dry yeast (80 billion cfu) had no effect on the ruminal bacterial community diversity. The inconsistency noted in these reports may be partly due to the feeding strategy, diet type, types and dosages of yeast used, physiological stage, stress, health status, and age of the animals [25]. The purpose of this review is to provide an overview on the use of yeast as a natural feed supplement for a healthy microbial population in the rumen, yeast adhesion properties and colonization resistance, cholesterol-lowering ability and immunostimulatory potential, animal performance, and productivity.

2 Production and sources of yeast products

Maintaining a healthy gut in animals is essential for sustainable animal production especially with the ban on antibiotics use as growth promoters [33]. A healthy gut is frequently associated with improved productivity in livestock [34]. One of the basic determining factors of a healthy gut is the diversity of the microbiome. It is widely known that mannan oligosaccharides (MOSs) in yeast influence the microbial population by feeding “the good bacteria” to the detriment of pathogenic/undesirable bacteria [11, 35]. Similarly, they are capable of secreting substances that can suppress the growth of some pathogens [36] which can be a viable food safety tool [37]. Administration of yeast (*S. cerevisiae*) offers better results in adult ruminants [38]. A recent study showed that yeast supplementation modifies the rumen microbiome, resulting in improved energy and protein supply in lactating cows fed diets containing low-quality forages [39]. Yeast supplementation has shown to stimulate the growth of beneficial microorganisms in the rumen, with higher number of anaerobic and cellulolytic bacteria [39, 40]. Yeast supplementation has also been reported to enhance organic acids production and vitamins (especially thiamine) to stimulate the growth of lactic acid bacteria and rumen fungi [41]. In a study with sheep, Liu et al. [42] reported that the relative abundance of *Candidatus_saccharimonas* and *Ruminococcus_gauvreauii* in high-NSCFR (ratio of non-structural carbohydrate to fat) groups was increased when supplemented with a yeast culture at 2.3 g/kg of feed. A significant increase in the relative abundance of *Butyrivibrio_2* was observed in the group on low-NSCFR + 2.3 g/kg yeast culture. In another lamb study, increasing the yeast dose resulted in an increase in the proportion of Firmicutes/Bacteroidetes ratio in the gut (Table 1) [10].

3 Properties of yeast adhesion and colonization resistance

The intestinal barrier, which includes the mucous layer, epithelial junction adhesion complex, antimicrobial peptides, and secretory IgA, is a major defensive mechanism that protects the organism from pathogens [42]. By attaching themselves to the intestinal mucosa, "beneficial bacteria" promote and enhance the gut and overall health of livestock. The gut of neonatal animals is naturally colonized with microorganisms, which generally originates from their mothers. Commercialization of food animals has significantly reduced their interaction with the environment thereby minimizing the intrinsic colonization of the gut, thereby increasing their exposure to intestinal infections by pathogens. However, probiotics, such as yeast supplements, can colonize these animals and limit the effects of these pathogens by competing with them. The ability of *S. cerevisiae* to be transformed into different multicellular phenotypes helps *S. cerevisiae* to adapt to its surrounding and exact positive effects in food animals [50, 51]. Studies have shown that mannan-oligosaccharides from yeast can adhere to various enteric pathogens, such as *Salmonella* [52, 53], *Campylobacter jejuni* [54], and *E. coli* serotypes [55], and reduce their ability to adhere to and invade host cells [56]. Inclusion of *S. cerevisiae* and/or its components may help protect calves that are vulnerable to Johne's disease [36]. In an in vitro study by Li et al. [36], they reported that inactive yeast and autolyzed yeast were more effective in inhibiting *Mycobacterium avium* spp. paratuberculosis adhesion to bovine mammary epithelial cell lines (MAC-T cells) and bovine primary epithelial cells compared to yeast cell wall components. The authors reported that adherence was reduced by about 10–30% in the presence of inactive yeast. This shows that the risk of *Mycobacterium avium* spp. paratuberculosis infection could be reduced in ruminants by using probiotics/prebiotics. Similarly, some in vivo studies on enteropathogenic bacteria, such as *Salmonella typhimurium*, *S. typhi*, and *E. coli* also confirmed the adhesive potential of *S. cerevisiae* [57, 58]. Moreover, results obtained by Li et al. [36] suggested that inclusion of *S. cerevisiae* could result in a decrease in Gram-negative pathogens and *Mycobacterium avium* spp. paratuberculosis in calves. Probiotics/prebiotics and their bioactive components have shown potentially high adhesive properties that may be useful against enteric pathogens. In an in vivo study, dietary supplements containing mannan-oligosaccharides from yeast increased the relative abundance of mucin secreting cells in sea bass [59]. The resultant increased in mucus concentration by MOS could minimize pathogen colonization by interfering with their ability to adhere on the membrane [36, 60], as well as via the physical properties of mucus that help to clear pathogenic bacteria [61]. Reports clarified that modification (oxidation and reduction) of mannan resulted in the upregulation of Th1/Th2 genes from dendritic cells (DCs) [62]. Th1 gene is vital in regulating *Mycobacterium avium* spp. paratuberculosis infection [62, 63]. Yeast probiotics and their co-cultured with yeast cell wall components can also affect commensal bacteria and protozoa that inhabit the ruminant gut. Increase in diversity and band number of bacteria in the ileum and colon of piglets [63] with MOS supplementation show that the gut microbiome, which can act as a protective barrier, could be stabilized by using mannan-oligosaccharides against *Mycobacterium avium* spp. paratuberculosis infection.

4 Fattening animals and average daily weight gain

Improving feed efficiency and growth rate are the current drivers of today's livestock enterprises, and these production variables can be achieved with feed supplements [27]. Due to broader distribution, storage, and application of dried yeast, it is more comprehensive as a dietary supplement. Depending on production technology, it can be administered as dead cells (MOS) or live cells (probiotics) [64]. Several publications have described the roles of *S. cerevisiae* in animal feeds. In a study on fattening lambs, Liu et al. [10] reported that dry matter intake and some meat variables were significantly increased with two inclusion levels of yeast supplementation compared to the control. Issakowicz et al. [24] reported a 9% higher carcass weight and a commensurate increase in external carcass length when a finishing lamb diet was supplemented with *S. cerevisiae*. Yeast supplementation significantly enhanced the production of butyric and propionic acid, which would promote

Table 1 Impact of yeasts on rumen microorganisms

Yeast product	Doses	Animal spices	Impacts	Reference
Yeast (BIOSAF SC 47	0.5 and 5 g/d	Holstein cows	Decrease of Prevotella and Mitsuokella genera Improved *Fibrobacter* and *Ruminococcus*) and stimulated lactate-utilizing bacteria (*Megasphaera*and *Selenomonas*)	[43]
Active yeast product (Actisaf Sc 47)	5 and 10 g/kg diet	Mid-to-late lactation Holstein cows	Increased fibrolytic bacterium *Fibrobacter*	[44]
Levucell SC 20. *S. cerevisiae* (CNCM I-1077)	0.5 g/animal/d	Buffalo bull	Enhanced bacteria and protozoa population	[45]
Live yeast	Yeast at 7.5×10^8 CFU/L before weaning and 3×10^9 CFU/kg	Calves	Increased total Lactobacilli population around weaning period	[46]
Live yeast	1 and 2 g live yeast or 20 g yeast cell wall polysaccharides/cow per d	Cattle	Higher digestibility of ADF and NDF; increased the population of F. succinogenes S85, Ruminococcus albus 7 and R. flavefaciens FD-1; decreased the percentage of Streptococcus bovis JB1	[47]
Live yeast	Live yeast at 15 g/d	Holstein steers	Increased the population of R. albus, R. champanellensis, R. bromii, R. obeum, M. elsdenii, Desulfovibrio desulfuricans, and D. vulgaris	[48]
Live yeast	Yeast at 3.3 g/kg of diet per d (1×10^{10} CFU/d)	Holstein cows	Increased the relative abundance of Bacteroidales, Lachnospiracea, and Flexilinea	[49]

the development of papillae in the rumen and enhance glucogenic acid absorption, resulting in an improvement in fattening animals. In a study with Shami goats and Awassi lambs, Titi et al. [27] reported an increase in live weight and growth rate in the group supplemented with yeast at 0.012.6 g/kg diet. However, no effect was observed on weaning live weight, average daily weight gain, eviscerated weight, and dressing percentage when lamb diets were supplemented with 0.5 and 1 g of live yeast daily. Magrin et al. [65] reported that Charolais bulls final body weight and average daily gain, carcass weight, and dressing percentage did not differ between groups fed a diet supplemented with *S. cerevisiae* CNCM I-1077 at 5 g/bull/day. However, the dry matter intake increased and tended to reduce the number of days required to finish the animals. Soren et al. [6] reported that inclusion of 15 g of *S. cerevisiae* in Malpura lamb diet had no effect on final body weight and average daily gain. Fadel El-seed et al. [66] reported that the average daily gain of Nubian kids was increased by about 167–250% when *S. cerevisiae* was supplemented at 2.5 and 5 g/day/kg in the diet. Pal et al. [23] observed an increase in average daily gain and feed intake in Black Bengal goat kids when their concentrate diet was supplemented with *S. cerevisiae* at 7×10^6 cfu/g. Adewumi [67] reported that inclusion of 5 g of yeast in the diet of West African Dwarf sheep fed crop residues improved the average daily gain. Chaucheyras et al. [18] reported that the use of yeast culture in combination with monensin in lamb diets improved the body weight gain. However, Magrin et al. [65] reported that the average daily gain did not differ between Charolais bull groups fed a diet supplemented with *S. cerevisiae* CNCM I-1077 at a dose of 5 g/bull /day. Furthermore, a recent meta-analysis conducted by [68] reported that probiotic yeast of *S. cerevisiae* origin improved body weight gain, and feed conversion ratio while it reduced feed consumption when included in broiler chicken diet at a dose less than 10 g/kg diet. Recently, He et al. [69] summarized that live *S. cerevisiae* included in broiler diets at 0.5 and 1.0 g/kg could be used as an alternative to antibiotics in improving growth performance, nutrient digestibility, immune function, intestinal morphology, and serum antioxidant capacity of broiler chickens. In general, based on the available information, some of which are discussed in the current review and in line with current research reports on probiotic yeast [68, 70, 71], it can be said that live yeast (*S. cerevisiae*) probiotics can act as potential alternatives to sub-therapeutic use of antibiotics to increase the performance and physiological responses of healthy and disease-challenged broilers as long as the appropriate level of incorporation, yeast type, biosecurity, and management procedures are strictly followed. Major findings on the role of yeast on the performance of animals are summarized in Table 3.

5 Cholesterol-lowering ability and immune stimulating properties

About 90% of the yeast cell wall is composed of 85% glucans, 16–22% mannan, and 2% chitin substances; however, the ratio of these components vary widely depending on strain, stage of growth, and environment [63, 72, 73]. These yeast-isolated components have been widely studied across different fields due to the beneficial effects of their bioactive compounds and relatively low price. The most and best-studied polysaccharides are glucan and mannan [74], and there is a growing demand for these yeast-derivatives in food agriculture and in other fields [75, 76]. These components are essential in improving the immune reactions and reducing cholesterol [77, 78]. In general, polysaccharides (such as glucan, mannan, and chitin) play an important role in the immune system [79].

In in vitro conditions, yeast lowers cholesterol by absorbing it in growing yeast cells (Fig. 1) [80]. Yeast contains *β-glucan* which is responsible in increasing the cholesterol breakdown by binding to bile acids in the gut. Additionally, yeast promotes short-chain fatty acid production, which in turn reduces hepatic cholesterol synthesis [81]. Supplementation of 10 g of live yeast reduced cholesterol and triglyceride levels in heifers compared to the control diet (without yeast) [82]. Another study reported a significant decrease in low-density lipoprotein cholesterol and triglyceride with *Saccharomyces cerevisiae* ARDMC1 inclusion without any effect on the concentration of high-density lipoprotein cholesterol in serum [83]. Studies have shown that *β-glucan* reduced levels of non-high-density lipoprotein-cholesterol fraction containing low-density lipoprotein cholesterol without affecting the levels of high-density lipoprotein cholesterol or triglyceride [84–86]. β-glucans are conserved structural components of the yeast cell walls, and studies have shown that *β-glucans* represent important molecules with significant immunomodulatory functions [87].

This represents an evolutionary highly conserved structure, often named (pathogen-associated molecular patterns) [88]. *β-glucan* can be considered as an evolutionary old stimulant of many defensive reactions, because it can stimulate immune reactions in a wide variety of species, including rabbits, sheep, goats, cattle, horses, dogs, pigs, monkeys, and humans [89]. Li et al. [36] found that when lymphocytes were stimulated with different concentrations of *S. cerevisiae*, β-glucan significantly induced cell proliferation. Microparticles of β-glucan could be used to synthesize different nanoparticle core-shells, and they will not only act as immune stimulants but also as antigen carriers [90]. Additionally, they could be applied to mucosal vaccination [45] and adding antibodies to the mix will further improve the specific target [91]. *β-glucan* provides multiple effects on various aspects of biological reactions, although the mechanisms of some of its functions are still unknown.

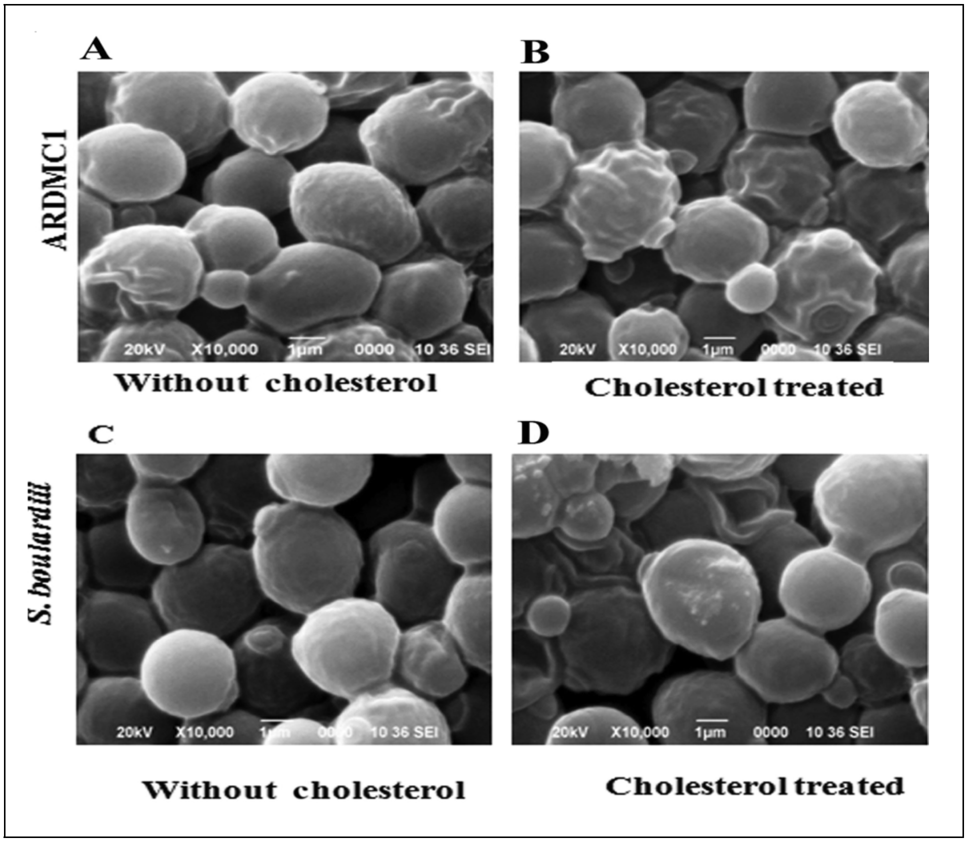

Fig. 1 This figure was adapted from [73]. **A** *Saccharomyces cerevisiae* ARDMC1 grown in yeast and mould broth without cholesterol. **B** *Saccharomyces cerevisiae* ARDMC1 grown with cholesterol. **C** *S. boulardii* grown in yeast and mould broth without cholesterol. **D** *S. boulardii* grown with cholesterol

Similar to β-glucan, mannan is a conserved structural component of yeast cell walls. Mannan is a molecule that supports the effective elimination of circulating lipoproteins [74, 92]. Levels of total cholesterol and triglycerides decreased significantly as well as the atherogenic low-density lipid (LDL) fraction when mannan was used at a rate of 50 mg/kg in mice with acute lipemia [74]. In the liver, triglycerides level decreased significantly, whereas the activity of chitotriosidase increased after mannan-induced macrophage stimulation [74, 93]. Hoving et al. [94] reported that mannan oligosaccharides (MOS) supplementation influenced the gut microbiota by decreasing plasma cholesterol levels and increasing fecal excretion of bile acid when using an experimental murine model with hyperlipidemic ApoE*3-Leiden. In veterinary medicine, yeast-derived-glucan and hydrolyzed mannan-rich fractions were proposed for use to improve cattle health [95]. Medzhitov and Janeway reported that yeast modulated the host immune system via a specific interaction with several immunocompetent cells [96].

6 Nutrient digestion and absorption

Yeasts are fed primarily as a digestive aid because they assist animals in extracting the most nutrients from feed. They are able to achieve this by supplying important enzymes, such as amylase, protease, lipase, and cellulase. Yeasts are considered as an excellent source of essential nutrients for the animals [97]. Yeasts are palatable and are known to stimulate appetite in animals and help to maintain maximum intake of dry matter by stimulating rumen fermentation and improving fiber digestion. Yeasts are generally considered safe, as recognized by the US Food and Drug Administration, and can help newly received animals to adapt to full feed faster while improving the rate of gain and/or feed conversion, thereby reducing the total feed cost per kg gain [44]. Several studies have shown that live yeast stimulated the growth of cellulolytic bacteria and increased fiber digestion of low-quality corn silage by 24% [98], increased weight gain [9], improved digestion and nutrient utilization [9, 98], and increased the production of volatile fatty acid (VFA) [99]. Yeast culture decreased rumen concentration of ammonia (NH_3-N), increased incorporation of NH_3 into microbial protein, and improved amino acid profile of duodenal digesta [56, 100]. *S. cerevisiae* supplementation manipulated rumen microbial population and resulted in improved energy and protein supply in lactating cows fed diets containing low-quality forages [35]. Dry matter intake and dressing rate increased significantly with yeast supplementation compared to the control. Titi et al. [27] reported an increase in nutrient digestion, and comparable live weight and growth rate in the yeast group and suggested that this was due to a change in rumen microbial ecology [35]. Inclusion of dietary probiotics (containing 2 strains of viable yeast and *E. faecium* and at 2×10^9 cells/day and 5×10^9 cfu/day) in the diets of dairy cows from 21 days before the expected calving date until 10 weeks postpartum led to a 2.3 kg/cow/day increase in milk yield. Yeast inclusion in the diet of ruminants is one way to increase the utilization of poor-quality roughages by supporting rumen microbes which enhances digestion of roughages and increase dry matter intake [101]. Increased enzymatic activity in the gastrointestinal tract of animals, due to probiotic yeast inclusion, could either be due to elevated production of additional enzymes due to the yeast. It could also be that live yeast and yeast fermentation products may increase the length of intestinal villi and villus-to-crypt ratios [61, 102], resulting in an increased surface area for nutrient absorption. From all these reports, it can be concluded that *S. cerevisiae* additives play crucial roles in the rumen by increasing the breakdown of dietary fiber and protein resulting in increased microbial protein, which is a major source of amino acids in the small intestine [103].

7 Milk yield and composition

Fungi and fungal products, including yeast, yeast extract, and fungal enzymes, increase milk yield by enhancing organic matter and fiber degradation in the rumen. Yeast supplementation in ruminant diets is a favorable option to increase the utilization of poor-quality roughages, grains, and by-product-based diets [104]. The response of dairy cows to *S. cerevisiae* (SC 47) inclusion at 5 g/day can result in a desired improvement in milk yield from 2 to 30%, but documented responses have been inconsistent and were affected by season, physiological state of the animal, age, stage of lactation, parity, feeding regime, and treatment of the animals [105]. In another study, average milk yield/day of lactating Saanen dairy goats that received *S. cerevisiae* at the rate of 4×10^9 cfu/day/animal was increased by 14% compared to the control group [106]. Uyeno et al. [44] reported that the addition of 5 g or 10 g of dried yeast in the diet of lactating cows in mid-to-late lactation had no effect on milk yield, milk protein, milk fat, and milk solid-not-fat. Degirmencioglu et al. [107] and Meller et al. [108] summarized some of the benefits of live yeast supplementation in dairy cattle, such as increase in milk yield and milk protein. Anjum et al. [99] reported that average daily milk production and 4% fat corrected milk (FCM) increased by 4.3% and 4.7%, respectively, in buffaloes fed diet supplemented with 14 g/head/day of yeast® (*S. cerevisiae*), but milk protein, fat, solids non-fat (SNF), and total solids were similar with the control group. Additionally, the somatic cell count (SCC) was lower in the group that received yeast® compared to those animals which received the control diet. Majdoub-Mathlouthi et al. [109] reported that inclusion of 5 g of *S. cerevisiae*/cow/day in the diet of primiparous and multiparous cows during the summer season increased milk yield by 16.4% for primiparous and of 22.8% for multiparous cows after 100 days. The values after 200 days were 8.9% and 17.4%, respectively. Rihma et al. [64] reported that the inclusion of 0.5 g/day/cow of yeast in the diet of Estonian Holstein cows had a significant effect on milk yield and a numerical increase in energy corrected milk, milk fat, and milk protein. Ajithakumar et al. [65] noted that supplements containing 100 g primed fat and 25 g *S. cerevisiae*/day in the diet of Murrah buffalos increased milk yield by 18.9% and milk fat by 6.16%; however, solid not fat, protein, lactose, and ECM were not affected by the supplementation. Additionally, Dehghan-Banadaky et al. [66] reported an improvement in milk fat when 4 g of live yeast was given to mid-lactation dairy cows during the hot season, but no effect was noted for fat corrected milk, 3.5% milk yield, and milk composition (protein, lactose, solid-not-fat, and total solids). Another study reported that daily milk yield (32.3 and 33.0 kg) and milk protein (1.08 kg) were greater for dairy cattle fed live yeast products at 3 g/cow/day [67]. Degirmencioglu et al. [107] reported that inclusion of *S. cerevisiae* at 30 g/buffalo cow/day improved milk yield of Anatolian water buffalos by 14.6% and 4% FCM by 24.7%. Desnoyers et al. [28] reported that the inclusion of 1.2 g/kg body weight of live yeast probiotics (containing *S. cerevisiae*) in ruminant diets (cattle, buffaloes, sheep, and goats) increased milk yield. As highlighted earlier, Bruno et al. [22] reported an increased milk yield, true protein, and solid-not-fat in heat-stressed Holstein lactating cows supplemented with 30 g of *S. cerevisiae* for 120 days. Bitencourt et al. [43] observed an increase of about 3–4% in the daily milk yield and milk constituents, such as protein and lactose in yeast-fed Holstein dairy cows in mid-lactation, but fat concentration in milk was similar among the groups. A significant reduction in the concentration of milk fat was observed in cows fed a diet supplemented with live yeast [29]. The above results indicate that inclusion of *S. cerevisiae* in dairy cow diets will increase milk yield and improve milk composition through enhanced feed digestibility (Table 2). On the contrary, several studies have reported no effect in production variables with yeast inclusion in the diets of dairy cows. There was no effect in milk yield with inclusion (2 weeks pre-partum and ending 14 weeks post-partum) of 10 g of *S. cerevisiae* /cow/day in Estonian Holstein Friesian cows. Although authors reported a reduction in milk protein and fat content from 40 days post-partum

Table 2 Impact of yeasts on milk production and milk composition

Yeast product	Doses	Animal spices	Impacts	Reference
S. Cerevisiae	5 g/cow/d	Cows in hot season	Improve milk yield by 22.8%	[100]
Yeast culture	10 g/cow/d	Estonian Holstein Friesian cows	Decrease milk fat and protein production	[106]
S. cerevisiae	25 g/d	Murrah buffalo	Milk yield and composition	[102]
Live yeast	4 g/cow/d	Mid-lactation dairy cows during hot season	Increased milk fat	[103]
S. cerevisiae	0.5 g/d	Cow	Improved milk yield by 2.5%	[101]
(*S. cerevisiae*)	30 g/cow/d	Anatolian water buffalo	Improved milk yield by 14.6%, fat corrected milk by 24.7%	[98]
Yeast		Holstein dairy cows	Increase in daily milk yields, milk protein, and milk lactose by 3.16%, 3.41%, and 4.27%	[105]
S. cerevisiae		Lactating dairy cows	Increased milk production by 1.18 kg/d, protein yield by 0.03 kg/d and milk fat yield by 0.06 kg/d, and energy-corrected milk by 1.65 kg/d	[110]
S. cerevisiae	4×10^9 cfu/animal/d	Lactating Saanen dairy goats	Increased average milk yield/day by 14%	[97]
Live yeast products	3 g/cow/d	Dairy cattle	Increased daily milk yield (33.0 kg) and milk protein (1.08 kg)	[104]
S. cerevisiae (SC 47)	5 g/d	Holstein dairy cows	Improved milk yield and average daily fat corrected milk	[96]

[110], *S. cerevisiae* supplementation had no effect on the chemical composition of milk, except milk fat which was significantly higher in the yeast group [31, 111]. Poppy et al. [30] reported that milk composition was not significantly affected by yeast supplementation (Table 3).

8 Fatty acid profiles of animal products

Milk fat depression is caused by biohydrogenation of dietary polyunsaturated fatty acids (PUFA) to SFA [115]. Fatty acid profile of meat and milk influences the health status

Table 3 Impact of yeasts on animal growth performance

Yeast product	Doses	Animal spices	Impacts	Reference
S. cerevisiae ITCCF 2094	5×10^9 cfu/h/d	Crossbred calves	Improved total body gain by 41.2%	[2]
S. cerevisiae	5 g/animal /d	Jersey heifer	Improved average final weight gain by 7.17% and lower feed conversion ratio by 12.6%	[7]
Live yeast cells	0.5 and 1 g/d	Lambs	Improved live weight, average daily weight gain, eviscerated weight, and dressing percentage	[22]
S. cerevisiae	15 g/kg of concentrate	Malpura lambs	Improved ADF digestibility by 25%	[3]
Simmental × Luxi F1 crossbred bulls	0.8 g dry yeast/bull per day and 50 g yeast culture/bull per day		No effects on intramuscular fat content or cholesterol content; decreased backfat thickness; an increased concentration of free fatty acids in the blood	[112]
Lambs	0.3 mg Cr enriched yeast/kg dry matter		Increase backfat thickness; higher meat pH; no effects on the fatty acid profile of meat	[113]
Live yeast cells	0.8 and 2.3 g of yeast/kg dietary dry matter	Small-tailed Han lambs	An increased concentration of linoleic acid concentration in the muscle; a decreased conversion of linoleic acid to stearic acid	[114]

Table 4 Impact of yeasts on fatty acid profile of animal product

Yeast product	Doses	Animal spices	Impacts	Reference
S. cerevisiae	25 g/day	Murrah buffalo	Lowered SFA by 12.18%, improved UFA by 30.14%, MUFA by 26%, PUFA by 39.30%, and linoleic acid (C-18:2) by 2.87%	[102]
S. cerevisiae	0.05 kg/animal/day and weekly increase by the same number	Lambs	No effect on fatty acid composition of intramuscular fat	[66]
S. cerevisiae	60, 120, or 180 g of yeast fermentation product/cow per d	Holstein cows	No effects on pH	[117]
S. cerevisiae	Yeast at 9.0×10^7 CFU/kg body weight	Lambs	No effects on pH	[118]
S. cerevisiae	5 g of live yeast/bull or (1×10^{10} CFU/bull per d)	Bulls	No effects on pH; increased acetate and butyrate concentrations; increased acetate:propionate ratio	[119]

of consumers in the long run. Consumption of food with a high cholesterol content and SFA is linked to cardiovascular diseases in humans. Consumption of cholesterol is not bad due to its importance in the reproductive system, but excess of it in the body will clog blood vessels and disturb the free flow of blood. Some studies reported that *S. cerevisiae* supplementation increased the digestion of organic matter and resulted in a higher energy for milk yield and decreased the mobilization of fat in buffalos [65, 99, 107]. In a previous study, there was a decrease in saturated fatty acids and an increase in unsaturated fatty acids when 100 g prilled fat and 25 g *S. cerevisiae* were added for 21 days pre-partum to 90 days postpartum in Murrah buffaloes [65]. No effect was observed in the fatty acid composition of intramuscular fat from lamb meat when yeast was added at 0.05 kg/ animal/ day (Table 4) [116].

Liu et al. [42] reported that 2.3 g/kg of yeast culture supplement in a lamb diet increased the content of polyunsaturated fatty acids and decreased the contents of saturated fatty acids and monounsaturated fatty acids. Fatty acids synthesis by microbes in the gut can be influenced by the prevailing gut pH [120], caused by dietary yeast inclusion [102], and/ or their interaction with dietary compositions [42]. Kidane et al. [121] reported that ruminal fluid pH, VFA concentrations, acetate to propionate ratio, and non-glucogenic to glucogenic VFA ratio were not affected by dietary treatments when soybean meal was replaced with yeast protein from *Cyberlindnera jadinii* in concentrate feeds.

9 Conclusions

Supplementation of yeast has been shown to promote milk fat and milk production in dairy cows as well as feed intake and growth rate in young ruminants. This could be related to the yeast ability's to accelerate fiber digestion and maintain rumen pH. Therefore, this review provides insight into yeast probiotics, which can modify the dynamics of microbial populations and hence confer health benefits to ruminants, improve animal productivity, weight gain, nutrient digestion and absorption, and overall animal welfare. Furthermore, yeasts have been implicated in reducing the incidence and severity of gastrointestinal pathogens, possibly by altering the balance of the beneficial and harmful microbes or causing an immunomodulatory response in the animal. Yeasts also have the ability to lower cholesterol, improve intestinal wall adhesion, and reduce colonization by pathogenic bacteria. Yeast probiotics appear to be promising antibiotic alternatives and can also improve animal welfare.

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Declarations

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