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Potential Application of *Saccharomyces cerevisiae* as an Antioxidant Agent for Broiler Chickens – A Brief Overview

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ABSTRACT

Broiler chicken strains and the intensive production system are typically attributed to the stress conditions in broiler production. The use of synthetic antioxidants is commonly practiced by the farmers to alleviate the adverse effects of stress on broiler chickens. Yet, excessive use of synthetic antioxidants can leave residues in broiler meats, which can be harmful to consumer health. As a probiotic, yeast *Saccharomyces cerevisiae* has been widely used as a feed additive by broiler producers. Beyond its probiotic properties, *S. cerevisiae* has also been demonstrated to have antioxidant properties and may therefore be exploited as an antioxidant agent for broiler chickens. However, the in-depth understanding about the potential use of *S. cerevisiae* as an antioxidant agent for broiler chickens is still limited. Hence, the overview regarding the application of *S. cerevisiae* as an alternative antioxidant agent for broiler chickens is of importance. The current review article elucidates the antioxidant potential of *S. cerevisiae,* the use of *S. cerevisiae* to increase the antioxidant activity of fermentation products, as well as the application of *S. cerevisiae* and its derivative products as an antioxidant agent in broiler production. Moreover, the potential application of *S. cerevisiae* as an anti-inflammatory agent for broiler chickens is also briefly discussed in this current review.

Keywords: Broiler, Gut health, Inflammation, Natural antioxidant, Stress, β-glucans.

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INTRODUCTION

Broiler production is one of the sectors that plays an important role in meeting society's animal protein needs while also contributing positively to the economy of various countries **(Sumanu *et al*., 2022)**. Farmers are currently raising broiler chickens intensively and in large numbers in order to achieve economic efficiency **(Sugiharto, 2022)**. According to **Gržinić *et al.* (2023)**, the intensive rearing system for broiler chickens (indoor open floor housing) can cause stress due to uncomfortable conditions. These stress conditions can be exacerbated when broiler chickens are overcrowded **(Sugiharto, 2022)**.

Other factors that may pose a threat to the comfort include climate change and global warming, which can result in heat stress in broiler chickens, particularly those housed in open houses **(Gržinić *et al.*, 2023)**. The use of environmentally controlled broiler houses is an alternative that can protect broiler chickens from environmental stressors. However, using this type of broiler house is very expensive, so not all farmers can afford it.

Oxidative stress in broilers is a significant concern due to its detrimental impact on productivity and overall health. It can result from various environmental and physiological stressors (**Sugiharto, 2019; Gržinić *et al.*, 2023**). Heat stress is one of the primary contributors to oxidative stress in broilers. One of the consequences of heat stress is the increase in reactive oxygen species (ROS), which are by-products of normal cellular respiration. When the production of ROS surpasses the capacity of antioxidant defenses, oxidative stress occurs, resulting in cellular damage, such as lipid peroxidation, protein oxidation, and DNA damage **(Shakeri *et al*., 2022; Apalowo *et al*., 2024)**. Dietary intervention with synthetic antioxidants (e.g., butylated hydroxytoluene [BHT], butylated hydroxyanisole [BHA], ethoxyquin, etc.) is commonly applied to reduce the negative impact of stress on poultry. However, excessive use of synthetic antioxidants can leave residues in broiler meats, which can be harmful to consumer health **(Sugiharto, 2019; Xu *et al*., 2021)**.

Farmers have been using yeast *Saccharomyces cerevisiae* as a feed additive following the prohibition of antibiotic growth promoters in broiler production. Numerous studies have demonstrated that *S. cerevisiae* is an effective probiotic that can enhance the health and productivity of broiler chickens **(Sugiharto *et al.*, 2019; Sumanu *et al.*, 2023)**. Apart from its probiotic properties, *S. cerevisiae* has also been shown to have antioxidant properties that can ameliorate the negative effects of stress on broiler chickens **(Het *et al.*, 2022; Sumanu *et al.*, 2023)**. In this respect, **Aluwong *et al.*, (2013)** and **Abo-Sriea *et al.*, (2024)** confirmed that selenium, β-glucans, and mannan oligosaccharides (MOS) found in *S. cerevisiae* have the capacity to scavenge excess free radicals or ROS in the bodies of broiler chickens under stress.

Currently, the published reviews discussing the potential use of *S. cerevisiae* as an antioxidant agent for broiler chickens are still lacking. Therefore, this article provides a short overview regarding the application of *S. cerevisiae* as an alternative antioxidant agent for broiler chickens.

Stress in broiler chicken production

Broiler chicken strains are types or strains of chicken that have the genetic potential to grow very quickly. However, despite their very high growth potential, broiler strains have several weaknesses, including poor cardiovascular health, a high prevalence of mortality, and being highly susceptible to ascites. Broiler strains are also highly susceptible to stress (e.g., heat stress and high-density stress) and have low welfare **(Riber and Wurtz, 2024).** In addition to stress due to high stocking density, intensive broiler chicken production is often negatively affected by excessive ammonia production in the broiler house. **Guo *et al.* (2023)** reported that excessive ammonia inhaled by chickens can cause an imbalance of antioxidants and oxidants in the broiler chicken's body, which can cause oxidative stress and immunosuppression. In fact, ammonia is the result of the decomposition of uric acid and undigested protein by broiler chickens involving special microorganisms **(Sugiharto *et al.*, 2023).** Ammonia production in the broiler house can be higher along with stress on the chicken, high stocking density, excessive protein content in the feed, high temperature, and poor litter management **(Sugiharto *et al.*, 2023).**

The imbalance between growth potential and immune capacity to face immune challenges or incoming pathogenic microorganisms makes broiler strains very susceptible to immune stress and disease during the rearing period **(Aylward *et al.*, 2024).** The term immune stress refers to several external factors that can affect chickens during the rearing period, such as pathogenic microorganisms, vaccination, and excessive use of drugs. These factors can affect the body's immune system and disrupt immune homeostasis in the body of broiler chickens **(Wang *et al.*, 2023).** Like stress due to heat or high stocking density, immune stress also has a negative effect on the productivity and health of broiler chickens.

Free radicals, especially ROS, play a very important role in the body's immune response to incoming pathogens. Typically, ROS are naturally produced in broiler chickens and can be exacerbated by stress **(Shakeri *et al.*, 2022; Apalowo *et al.*, 2024).** Indeed, excessive ROS production can pose a threat to the body because ROS has the potential to damage proteins and nucleic acids, resulting in tissue damage and causing negative effects on the physiological conditions, health and growth of broiler chickens **(Wang *et al.*, 2021).** To prevent the body from oxidative damage due to stress, the animal body has an enzymatic (superoxide dismutase [SOD], glutathione peroxidase [GPx], catalase [CAT]) and non-enzymatic (glutathione [GSH]) antioxidant system in cells. SOD can convert superoxide anions into oxygen and hydrogen peroxide, which are then broken down into water by antioxidant enzymes including GPx and CAT. GPx plays a role in protecting the structure and function of cell membranes from disruption and oxide damage **(Luo *et al.*, 2003).** However, when the activity of antioxidant enzymes decreases, polyunsaturated fatty acids will be attacked by ROS. The latter condition will lead to lipid peroxidation, resulting in malondialdehyde (MDA) production **(Cheng *et al.*, 2020).**

Antioxidant potential of *S. cerevisiae*

Farmers have frequently employed synthetic antioxidants to mitigate the detrimental effects of stress on the health, productivity, and physiological conditions of broiler chickens. In addition to being applied as anti-stress agents for broiler chickens, synthetic antioxidants are also often applied to feed (mixed into feed) to inhibit or prevent nutrient oxidation in feed so that feed quality is maintained **(Sithole *et al.*, 2023).** However, **Sugiharto (2019) and Xu *et al.* (2021)** have confirmed that the use of synthetic antioxidants in excess or improperly can result in residue on meats, which could pose a health risk to consumers. In this respect, excessive use of butylated hydroxytoluene (BHT) can induce apoptosis and encourage tumorigenesis.

Likewise, butylated hydroxyanisole (BHA) metabolites are also involved in the carcinogenicity process **(Xu *et al.*, 2021).** Based on these conditions and to ensure the sustainability of the broiler chicken industry, it is necessary to find alternative natural antioxidants to replace synthetic antioxidants for broiler chickens. Several strategies have been implemented, including using natural ingredients as a source of antioxidants for broiler chickens. The use of natural antioxidant sources is expected to be effective in alleviating the negative effects of stress on broiler chickens, as well as providing proof that broiler chicken products are safe for consumers who are becoming more health conscious. Among these natural antioxidants, broiler farmers often use plant extracts or herbal ingredients as a source of natural antioxidants for broiler chickens **(Zdanowska-Sąsiadek *et al.*, 2019).**

Another studies also report the potential of probiotic microorganisms and postbiotics (metabolites that are produced by probiotic microorganisms and exhibit biological activity to the host) as alternative sources of natural antioxidants for broiler chickens **(Rakngam *et al.*, 2024).** Probiotics are defined as live microorganisms that, when administered in adequate amounts, confer a health benefit on the host **(Sugiharto, 2016; 2022).** According to **Sugiharto (2016)**, probiotics can improve the health and productivity of broiler chickens by boosting the immune system, colonization resistance against infections, and the host intestine microbial balance. Lactic acid bacteria, *Bacillus* species, and specific yeast strains are some of the most commonly employed microorganisms as probiotics for broiler chickens **(Sugiharto, 2016; 2019).**

S. cerevisiae is a yeast that has been widely known by farmers to have the potential as a probiotic for broiler chickens. *S. cerevisiae* is also reported to have the potential as a prebiotic for broiler chickens so that it can replace the role of antibiotic growth promoters **(Ahiwe *et al.*, 2021).** In addition, several studies have reported the potential of *S. cerevisiae* as a source of natural antioxidants that are very potential to be applied to broiler chickens **(Attia *et al.*, 2022; Mohamed *et al.*, 2022). Makky *et al.*, (2021)** reported that the antioxidant potential of *S. cerevisiae* is closely related to the secondary metabolites produced by the yeast, namely tryptophol. Tryptophol is a metabolic derivative of tryptophan that has the ability to scavenge free radicals in the body. **Fakruddin *et al.*, (2017)** further reported that *S. cerevisiae* exhibits very strong metal chelating activity so that it can function as a very potential source of antioxidants. In this case, the ability of metal chelating activity is very important because it can reduce the concentration of metals that have a catalytic effect on lipid peroxidation.

In addition, metal chelating agents are considered secondary antioxidants because they can reduce the oxidation-reduction (redox) potential and thus stabilize oxidized metal ions **(Fakruddin *et al.*, 2017).** *S. cerevisiae* is also a source of GSH, which is an endogenous antioxidant compound found in all eukaryotic cells **(Santos *et al.*, 2022).** In this case, GSH can function as an antioxidant in conditions where broiler chickens experience stress due to its low reduction potential. GSH can also provide a protective effect against free radicals, either by reacting directly with free radicals or acting as a cofactor for redox enzymes such as glutathione reductase, GPx, glutaredoxin (thioltransferase: serves a crucial role in cellular redox regulation), and glutathione S-transferase (GST) **(Santos *et al.*, 2022; Abd El-Hamid, 2024).**

In addition to GSH, the antioxidant activity of *S. cerevisiae* is largely determined by the content of sulphur-containing amino acids and Maillard reaction products in the yeast **(Hassan, 2011).** Sulphur-containing amino acids are involved in the synthesis of intracellular antioxidants such as glutathione and N-acetyl cysteine **(Atmaca *et al.*, 2004; Colovic *et al.*, 2018).** Maillard reaction products are natural antioxidants that are formed mainly during the fermentation process of *S. cerevisiae* **(Hassan, 2011).** *S. cerevisiae* is one of the sources of MOS extracted from its cell walls. According to **Zhao *et al.* (2022),** MOS extracted from *S. cerevisiae* shows excellent free radical neutralization activity, so that it can be used as a source of natural antioxidants for broiler chickens. It is further explained that the free radical scavenging potential of MOS can be caused by the presence of carboxyl groups in MOS. However, it should be noted that the antioxidant activity of MOS from *S. cerevisiae* is greatly influenced by the molecular weight, glycosidic bonds, and sulfation level of MOS **(Zhao *et al.*, 2022).**

The use of *S. cerevisiae* has been reported to improve antioxidant status in broiler chickens both under commercial conditions and stress conditions **(Abo-Sriea *et al.,* 2024; Al-Abdullatif *et al.*, 2024**). In general, the use of *S. cerevisiae* can increase SOD and CAT activity and decrease MDA levels in serum, liver, and other tissues or organs such as intestines **(He *et al.*, 2021; Wang *et al.*, 2021)**. The use of *S. cerevisiae* has also been reported to reduce MDA levels in breast meat and decrease thiobarbituric acid reactive substances (TBARS) in meat during storage **(Mohamed *et al.*, 2022; Sumanu *et al.*, 2023)**. The use of *S. cerevisiae* can also decrease the heterophil-to-lymphocyte (H/L) ratio, which indicates a decrease in physiological stress in broiler chickens **(Attia *et al.*, 2022)**. **Al-Abdullatif *et al.,* (2024)** reported that hydrolyzed *S. cerevisiae* can maintain the balance of antioxidants and prooxidants in the body of broiler chickens under heat stress conditions so that the nuclear factor kappa-light-chain enhancer of activated B cells (NF-kB) and nuclear factor erythroid 2-related factor 2 (Nrf2) can be balanced.

In line with this study, **Wang *et al.,* (2021)** reported that from a molecular perspective, *S. cerevisiae* supplementation resulted in beneficial changes in the relative gene expression of Nrf2-related mRNA. Nrf2 is a transcription factor that can regulate the expression of antioxidant-related genes such as heme oxygenase-1 (HO-1), GPx, and SOD. The Nrf2 and NF-κB pathways essentially regulate cellular responses to oxidative stress, with Nrf2 protecting against oxidative stress and NF-κB regulating inflammatory responses in the body. The Nrf2 pathway inhibits NF-κB pathway activation by increasing antioxidant defenses and HO-1 expression, which efficiently neutralizes ROS, thereby reducing ROS-mediated NF-κB activation **(Yerra *et al.*, 2013)**. Recent reports also confirm the ability of *S. cerevisiae* to affect the hypothalamic-pituitary-adrenal (HPA) axis in broiler chickens under stress conditions **(Sumanu *et al.*, 2024)**. The latter investigators further confirmed that the use of *S. cerevisiae* can help neutralize ROS, thereby reducing oxidative stress and supporting better thermal regulation. Such a condition may therefore control the HPA axis and corticosterone production during heat stress **(Sumanu *et al.*, 2024)**.

The possibilities of *S. cerevisiae* being able to improve antioxidant status in broiler chickens have also been confirmed by several researchers. **Aluwong *et al.*, (2013)** and **Abo-Sriea *et al.*, (2024)** reported that β-glucans and MOS in *S. cerevisiae* have the ability to scavenge free radicals, whose presence increases due to stress conditions in broiler chickens. In line with this study, **Wang *et al.*, (2021)** reported that β-glucans and MOS in the cell walls of *S. cerevisiae* play a significant role in increasing antioxidant capacity in the body of broiler chickens. Furthermore, **Aluwong *et al.*, (2013)** reported that the sodium selenite fraction of *S. cerevisiae* also plays a role in increasing antioxidative activity in broiler chickens under stress conditions. In line with the study above, **Wang *et al.*, (2021)** reported that the cell wall components of *S. cerevisiae* containing β-glucans and MOS, in addition to increasing the activity of antioxidant-related enzymes, can also reduce ROS production and lipid peroxidation levels, resulting in a decrease in MDA levels in blood and tissues in broiler chickens.

S. cerevisiae has been studied for the modulation of the heat shock protein 70 (HSP70) in broiler chickens **(Al-Abdullatif *et al.*, 2024)**. HSP70 is a vital protein that plays a crucial role in stress response by helping to maintain protein integrity during stress conditions. Environmental factors such as high temperature and other stress factors significantly impact HSP70 expression in broilers. For instance, exposure to high temperatures can increase HSP70 expression, which helps the birds cope with heat stress **(Najafi *et al.*, 2015)**. The work by **Al-Abdullatif *et al.*, (2024)** showed that supplementing with hydrolyzed yeast *S. cerevisiae* reduced the duodenal mRNA expression of HSP70. According to this, giving broiler chickens exposed to heat stress a supplement of hydrolyzed yeast may enhance intestinal redox equilibrium, suggesting the potential benefits of yeast in enhancing stress resilience.

The use of *S. cerevisiae* to increase the antioxidant activity of fermentation products

S. cerevisiae is a type of yeast that is widely applied in the production of fermented products that can be used in the food industry or as animal feed. Typically, fermented products of *S. cerevisiae* experience increased nutritional value, especially increased amino acid and vitamin B content, and decreased anti-nutritional factors compared to products before fermentation **(Prabhu *et al.*, 2016; Qiu *et al.*, 2025).** Furthermore, the use of *S. cerevisiae* as a fermenter has been reported to increase antioxidant activity in fermented products. In this case, **Setiyoningrum *et al.* (2022)** reported an increase in antioxidant capacity, total polyphenols, alkaloids, and total flavonoids in garlic fermented with *S. cerevisiae*. In line with that, **Ejuama *et al.* (2021)** also reported an increase in the quantity of phenolic compounds and antioxidant activity with fermentation using *S. cerevisiae* in roselle calyx aqueous extract. **Darwesh *et al.* (2023)** also reported an increase in antioxidant activity, total phenols and flavonoids in cinnamon following the fermentation using *S. cerevisiae*. In the latter case, the *S. cerevisiae* fermentation process increased p-hydroxybenzoic acid, gentisic acid, catechin and chlorogenic acid so that it had an impact on increasing antioxidant activity in cinnamon **(Darwesh *et al.*, 2023).**

Another example was reported by **Chandra *et al.* (2024)** who reported an increase in phenols, flavonoids and antioxidant activity in *Orthosiphon stamineus* Benth leaves after fermentation using *S. cerevisiae*. Another example was presented by **Jelena and Yustiantara (2021),** where there was an increase in antioxidant activity in green coffee beans after fermentation using *S. cerevisiae*. Fermentation using *S. cerevisiae* was also reported to increase alkaloids, saponins, flavonoids, phenolics, and antioxidant activity of flaxseed extracts **(Ghosal *et al.*, 2021).** An increase in polyphenols, flavonoids and total antioxidant capacity (TAC) in wheat bran after fermentation using *S. cerevisiae* was also reported by **Prabhu *et al.* (2016).** Moreover, **Afriliana *et al.* (2023)** documented that fermentation using *S. cerevisiae* was able to enhance antioxidant activity, phenolic compounds, flavonoids, and tannins of Robusta coffee beans.

The literature shows that most yeast have the ability to produce **antioxidants (Sugiharto, 2019). Liang *et al.* (2023)** reported that glycosidic bonds in phenolic compounds are hydrolysed during fermentation, resulting in the formation of additional phenolic metabolites such as gallic acid, protocatechuic acid, and quercetin, thereby increasing antioxidant activity in the fermented material. During the fermentation process, yeast is able to produce enzymes that can break down glycosidic bonds in several phenol hydroxyl groups bound to complex compounds and this degradation in turn increases the amount of free phenol **(Ejuama *et al.*, 2021).** According to **Setiyoningrum *et al.,* (2022),** increasing the flavonoid content in fermented products using *S. cerevisiae* is also possible because there is an increase in acid during fermentation which frees the bound flavonoid component. A more recent study by **Anggraeni *et al.,* (2025)** further showed that fermentation using *S. cerevisiae* can increase the selenium content in infertile egg powder, thereby increasing antioxidant activity in the fermentation product. Moreover, **Wang *et al.*, (2025)** reported that *S. cerevisiae* fermentation was capable of reducing the molecular weight and modifying the structure of plant polysaccharides and thereby augmenting the antioxidant protective action of plant polysaccharides. Indeed, the latter feature is beneficial in protecting cells from oxidative damage induced by free radicals **(Wang *et al.*, 2025).**

Several *in vivo* studies have evaluated the *S. cerevisiae* fermentation products to improve the antioxidant status of broiler chickens. **Sobotik *et al.* (2022)** and **Heinsohn *et al.* (2024)** reported a decrease in plasma corticosterone and H/L ratio in broiler chickens given *S. cerevisiae*-fermentation products under heat stress conditions. It was most likely that *S. cerevisiae* fermentation products are able to modulate the gut microbiome of broiler chickens. Considering that gut microbiota has a critical role in regulating broiler thermogenesis through the gut-brain axis, the ability of yeast-fermentation products to modulate gut microbiome may therefore be beneficial for thermoregulation in broiler chickens **(Heinsohn *et al.*, 2024)**.

Another study by **Aristides *et al.* (2018)** demonstrated the efficacy of *S. cerevisiae* fermentation products in improving the meat quality of broiler chickens. In such cases, flavonoids and vitamin E present in the *S. cerevisiae*-fermentation products are responsible for reducing lipid oxidation in broiler chicken meats and therefore increasing the shelf life of meats (**Aristides *et al.*, 2018).**

Moreover, the use of *S. cerevisiae*-derived yeast fermentate was able to improve the antioxidant capacity in broiler chickens exposed to acute and chronic stress during the rearing period in the study of **Nelson *et al.* (2020)**. They confirmed that the use of *S. cerevisiae*-derived yeast fermentate reduced melanocortin-2-receptor (MC2R: the adrenocorticotropic hormone receptor on adrenocortical cells, serving a critical role in regulating cortisol production in the adrenal glands) gene expression. The reduced MC2R gene expression may consequently reduce corticosterone production and alleviate stress conditions in broiler chickens **(Nelson *et al.*, 2020).**

Application of *S. cerevisiae* and its derivative products as antioxidant agents in broiler production

In commercial broiler production, *S. cerevisiae* and its derivatives have gained significant attention for their potential as alternative antioxidant agents. The utilization of these yeast products is primarily driven by the pressing need to find sustainable alternatives to synthetic antioxidants, which have been traditionally used to maintain the antioxidative status of broiler chickens but now pose risks of synthetic antioxidant residues in broiler meat products **(Bilal *et al.*, 2021).** Antioxidants are crucial in poultry production as they help mitigate oxidative stress, a significant challenge in enhancing growth performance and health in broilers. In addition to improving gut health and immune competency, yeast products and their derivatives can increase broiler antioxidant capacity, making them a possible substitute for synthetic antioxidants and antibiotics for broiler production **(Obianwuna *et al.*, 2024).**

A number of studies have been carried out to evaluate the efficacy of *S. cerevisiae* and its derivatives as natural antioxidants for broiler chickens **(Table 1).** In addition to the improved antioxidant status and physiological response to stressors, using *S. cerevisiae* and its derivatives as antioxidant agents enhances broiler chicken production performance and health. Under commercial conditions, **Abo-Sriea *et al.* (2024)** used NutriFix® (consisting of *S. cerevisiae*, MOS and β-glucan) as a feed additive for broilers. They found that such dietary treatment improved growth performance, feed conversion ratio, intestinal health, immune responses and antioxidant capacity of broiler chickens.

Al-Abdullatif *et al.* (2024) also revealed that hydrolyzed *S. cerevisiae* supplementation improved duodenal redox homeostasis and the immune system, and hence improved growth performance and feed efficiency, as well as decreased the mortality rate of broiler chickens during heat stress. During stress conditions, dietary administration of *S. cerevisiae* also improved the meat quality of broiler chickens, as indicated by the reduced MDA and TBARS contents in meat **(He *et al.,* 2022; Mohamed *et al.,* 2022).** The latter condition may therefore increase the shelf life of broiler meats during storage **(Aristides *et al.*, 2018; Mohamed *et al.,* 2022).**

Table 1: Application of *S. cerevisiae* and its derivative products as an antioxidant agent in broiler production.

S. cerevisiae products	Levels in feed/water	Conditions during rearing	Effects on broiler chickens	References
S. cerevisiae-fermented infertile egg flour	0.7% feed	Challenged with high-stocking density	Decreased serum SOD level with no effect on serum MDA level	**(Anggraeni *et al.,* 2025)**
Activated *S. cerevisiae* (1 10^{10} cells/g)	0.75 g/kg feed	Infected with *Clostridium perfringens*	Increased TAC and reduced MDA levels in serum	**(Al-Baadani *et al.,* 2025)**
Inactivated *S. cerevisiae* (1 10^{10} cells/g)	0.75 g/kg feed	Infected with *C. perfringens*	Increased TAC and reduced MDA levels in serum	**(Al-Baadani *et al.,* 2025)**
NutriFix® (*S. cerevisiae*, MOS and β-glucan)	250 g/ton of feed	Reared under commercial conditions	Increased serum TAC	**(Abo-Sriea *et al.,* 2024)**
Hydrolysed yeast derived from *S. cerevisiae*	400, 800, or 1,200 mg/kg feed	Exposed to heat stress	Decreased duodenal mRNA expression of heat shock protein 70 (HSP70)	**(Al-Abdullatif *et al.,* 2024)**
Concentrated *S. cerevisiae* fermentation product	0.625 kg/metric ton feed	Challenged with overcrowding condition and heat stress for 12 hours	Reduced corticosterone levels and H/L ratio	**(Heinsohn *et al.,* 2024)**
Enzymatically treated yeast (*S. cerevisiae*)	1 and 2 g/kg feed	Coccidia challenge condition	Increased serum CAT activities	**(Alagbe *et al.,* 2023)**
Commercial *S. cerevisiae*	1 g/kg feed	Exposed to heat stress	Reduced MDA level in breast meat	**(Sumanu *et al.*, 2023)**
Commercial *S. cerevisiae* (12×10^9 active yeast per gram)	0.02% or 0.04% of feed	Reared under commercial conditions	Decreased H/L ratio, serum MDA level, and TAC	**(Attia *et al.,* 2022)**
Live yeast (*S. cerevisiae*; 1×10^{10} cfu/g)	500 and 1000 mg/kg feed	Transport stress condition	At 1000 mg/kg feed enhanced TAC and reduced MDA in serum and muscles	**(He *et al.,* 2022)**
Commercial *S. cerevisiae*	5% of feed	Exposed to heat stress	Increased CAT, GPx and SOD activities, and decreased MDA level in serum and TBARS in meat at days 1, 7 and 30 of storage	**(Mohamed *et al.,* 2022)**
S. cerevisiae and phytase co-fermented wheat bran	5 and 10%	Reared under commercial conditions	Increased mRNA expression of Nrf2 on chicken peripheral blood mononuclear cells	**(Chuang *et al.,* 2021)**

Live yeast (*S. cerevisiae*; 47,1 × 10^{10} cfu/g)	500 and 1000 mg/kg feed	Reared under commercial conditions	Increased SOD and CAT activities and decreased MDA level in serum	**(He *et al.,* 2021)**
Yeast (*S. cerevisiae*)-derived product	50, 100 and 150 mg/kg	Reared under commercial conditions	At 50 to 100 mg/kg improved jejunal antioxidant capacity (increased GSH, SOD, GPx activities and decreased MDA level)	**(Wang *et al.,* 2021)**
Selenium-enriched *S. cerevisiae* (10^8 cfu/g)	1 g/kg feed	Reared under commercial conditions	Increased GPx and thioredoxin reductase activities and TAC, and decreased MDA level in meats	**(Hou *et al.,* 2020)**
Se-enriched *S. cerevisiae*	0.15, 0.5 and 1.5 mg per kg of diet	Reared under commercial conditions	Improved antioxidant status (increased GPx, SOD and TAC and lowered MDA in plasma and liver)	**(Chen *et al.,* 2017)**
S. cerevisiae culture	0.5 mL/L of drinking water daily	Reared under commercial conditions	Enhanced serum antioxidant enzyme (GPx) activities	**(Aluwong *et al.,* 2013)**

CAT= catalase, cfu= colony forming units, GPx= glutathione peroxidase, GSH= glutathione, H/L ratio= heterophils to lymphocytes ratio, MDA= malondialdehyde, MOS= mannan oligosaccharides, Nrf2= nuclear factor erythroid 2-related factor 2, SOD= superoxide dismutase, TAC= total antioxidant capacity, TBARS= thiobarbituric acid reactive substances.

Potential application of *S. cerevisiae* as an anti-inflammatory agent for broiler chickens

It is generally known that stress not only causes oxidative stress but also causes inflammation in broiler chickens. In this case, stress may induce the secretion of hormones such as corticosterone, which can cause oxidative stress and can also initiate the inflammatory pathways. Indeed, oxidative stress and inflammation are interrelated, as each can exacerbate the other **(Ramos-González *et al.*, 2024).** In addition to being used as anti-stress agents, antioxidants are also often used by farmers to alleviate inflammation in broiler chickens under stress conditions. With regard particularly to *S. cerevisiae*, **Wang *et al.,* (2016)** reported that the use of live *S. cerevisiae* alleviated intestinal inflammation in broiler chickens infected with *Escherichia coli* by reducing NF-κB and interleukin (IL)-1β expressions in the ileum. Furthermore, **Lin *et al.,* (2023)** reported that the use of *S. cerevisiae* hydrolysate improves antioxidant status, reduces the expression levels of intestinal inflammatory factors, and alleviates the intestinal inflammatory response of broilers. In the above case, the *S. cerevisiae* hydrolysate may exert an anti-inflammatory effect by inhibiting the excessive expressions of IL-1β, IL-6, and tumor necrosis factor (TNF)-α. In addition, *S. cerevisiae* hydrolysate has the potential to improve the microbial population in the intestine, thereby positively influencing the inflammatory response in the intestine of broiler chickens **(Lin *et al.*, 2023).** In line with the above study, **Yang *et al.* (2019)** also reported that the use of *S. cerevisiae*-fermented product reduced the inflammation-related mRNA as indicated by the reduced IL-1ß, inducible nitric oxide synthase (iNOS), interferon (IFN)-γ, and NFκB mRNA expressions in the peripheral blood mononuclear cells of broiler chickens. In agreement with **Lin *et al.* (2023), Yang *et al.* (2019)** also confirmed that the decrease in the population of pathogenic bacteria in the intestine (e.g., *Clostridium perfringens*) due to treatment using *S. cerevisiae*-fermented product had an impact on the decrease in the amount of pro-inflammatory cytokines in the intestine of broiler chickens.

It is further explained that β-glucans contained in *S. cerevisiae* play a significant role in inhibiting IL-1ß production and thereby reducing NF-κB-mediated inflammatory responses **(Yang *et al.*, 2019).** Another study by **Chuang *et al.,* (2021)** also demonstrated the anti-inflammatory effect of *S. cerevisiae* in broiler chickens. They reported that the use of *S. cerevisiae* and phytase co-fermented wheat bran in feed could inhibit the expression of IL-1β, which is one of the main regulators of inflammation in broiler chickens. Again, components of the *S. cerevisiae* cell wall, especially β-glucans and MOS, have a very critical role in reducing inflammatory-related cytokine release so that the negative effect of stress on inflammation can be reduced **(Chuang *et al.*, 2021).** Another study further reported that *S. cerevisiae* hydrolysate showed anti-inflammatory effects in broiler chickens **(Wang *et al.*, 2022).** The latter authors revealed that *S. cerevisiae* hydrolysate reduced TNF-α concentration, IL-6, IL-1β, TNF-α and NFκB, while increasing IL-10 expression levels in the jejunum of broiler chickens. In line with other studies, the anti-inflammatory effect of *S. cerevisiae* hydrolysate is closely related to β-glucans and MOS in *S. cerevisiae,* which can serve as anti-inflammatory agents.

CONCLUSIONS

The potential of *S. cerevisiae* as a source of natural antioxidants for broiler chickens is largely related to the content of several active ingredients in the yeast, such as tryptophol, GSH, sulfur-containing amino acids and Maillard reaction products. The antioxidant potential of *S. cerevisiae* is also closely related to β-glucans and MOS, which are the main components of the cell wall of the yeast. Dietary supplementation with *S. cerevisiae* has been shown to enhance antioxidant enzyme activity and reduce oxidative markers in broilers. In such cases, the active components in yeast, as mentioned above, play a major role in neutralizing ROS and preventing lipid peroxidation, especially under stress conditions. *S. cerevisiae* also plays a very important role in improving the response of broiler chickens to stress so that the negative consequences of stress can be alleviated. The sustainability of broiler production will greatly benefit from a field commercial study investigating the efficacy of *S. cerevisiae* and its derivatives as antioxidant agents and as substitute antibiotic growth promoters. Further research on the dose-dependent effects of *S. cerevisiae* and its derivatives as antioxidants and substitute antibiotics is also crucial.

Conflict of interests

We declare having no conflict of interest

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