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酵母培养物生物学功能及其在畜禽生产中应用的研究进展

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摘要:我国农业农村部第194号公告指出自2020年7月1日起,饲料生产企业停止生产含有促生长类药物饲料添加剂(中药类除外)的商品饲料,畜牧业正式进入“饲料端全面禁抗”时代。因此,加快绿色、高效饲用抗生素替代品的研发和应用,是当前畜禽养殖领域迫切需要解决的问题。酵母培养物(YC)作为一种绿色功能性添加剂,具有安全无残留的优势,在动物体内发挥多重生物学功能,在畜牧生产中具有较高的应用潜力。酵母培养物是酵母菌在特定工艺条件下经培养基充分厌氧发酵而成的一种微生态制剂,主要成分包括酵母细胞内容物、细胞外代谢产物、变形培养基和酵母细胞壁等。酵母培养物对畜禽机体健康的改善以及对畜牧产业发展的推动主要体现在以下几个方面:(1)酵母细胞壁内的活性物质β-葡聚糖等可以抑制促炎因子表达和激活机体的免疫应答系统来增强机体免疫力;(2)酵母培养物中的甘露寡糖可通过增加血浆抗氧化酶的活性来增强抗机体氧化功能;(3)酵母培养物可与病原体竞争粘附位点和调节胃肠道酸性环境,通过抑制有害病原体繁殖和促进耐酸有益菌增殖的方式来改善消化道健康;(4)酵母培养物可缓解热应激、提高繁殖性能以及改善蛋品质等。笔者在国内外相关研究基础上,重点从酵母培养物的抗炎及免疫调节、抗氧化应激和改善肠道屏障等生物学功能及其在反刍动物、猪和鸡中应用效果进行综述,并对酵母培养物在实际生产应用中存在的问题和前景进行探讨,以期为深入研究酵母培养物在畜禽生产中的合理应用提供参考。

关键词:酵母培养物;抗氧化功能;生长性能;畜禽生产
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Advance on the Biological Functions and the Application in Livestock and Poultry Production of Yeast Cultures

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Abstract: Announcement No.194 of the Ministry of Agriculture and Rural Affairs of the People's Republic of China pointed out that since July 1, 2020, feed production enterprises have restricted the production of commercial feed containing antibiotic growth promoters, and animal husbandry has officially entered the era of "antibiotics is completely banned in the feed industry". Therefore, accelerating the development and application of green and efficient feed antibiotic alternatives is an urgent problem in the field of livestock and poultry production. Yeast culture, a green functional additive which has the property of safety and without residue, provides various biological functions for animals and has high application potential in animal production. Yeast culture is a kind of microecological preparation, which is formed by the sufficient anaerobic fermentation of yeast under specific conditions, mainly including yeast cell contents, extracellular metabolites, deformed media, and yeast cell walls. Accumulating evidence indicated that yeast culture could improve the health of livestock and poultry and promoted the development of animal husbandry industry. (1) β-glucan, the active component of the yeast cell wall, can inhibit the expression of pro-inflammatory cytokines and activate the immune response system to enhance immunity; (2) Manno-oligosaccharides of yeast culture can enhance antioxidant property by increasing the activity of antioxidant enzymes in plasma; (3) Yeast culture can compete with pathogens for adhesion sites and regulate the acidic environment of the gastrointestinal tract. Besides, it can improve digestive tract health by inhibiting the reproduction of pathogens and promoting the proliferation of acid-resistant beneficial bacteria, thereby improving the growth performance of animals; (4) Yeast culture can alleviate heat stress and improve reproductive performance and egg quality. This review focuses on the biological functions of yeast culture (i.e., anti-inflammatory, immunomodulation, antioxidant property, enhancement of intestinal barrier function) and its applications in ruminants, pigs and chickens and discusses the problems and prospects of yeast culture in practical production and applications, providing reference for rational application of yeast culture in livestock and poultry production.

Keywords: yeast culture; antioxidant function; growth performance; livestock and poultry production

酵母培养物(yeast culture,YC)是酵母菌(*Saccharomyces*)在特定工艺条件下经培养基充分厌氧发酵而成的一种微生态制剂[1],酵母菌属于兼性厌氧的单细胞真菌,具有庞大的家族系统[2],包括酿酒酵母(*Saccharomyces cerevisiae*)、产阮假丝酵母(*Candida utilis*)和卡氏酵母(*Saccharomyces carlsbergensis*)等1 000余种[3]。其中,在畜禽生产中使用最广泛的是酿酒酵母菌[4]。酵母培养物主要由酵母细胞内容物、细胞外代谢产物、变形培养基和酵母细胞壁组成,富含氨基酸、小分子肽、寡糖和维生素等多种功能成分(表1)[5]。与抗生素相比,酵母培养物对动物无毒副作用,长期使用不会产生耐药性,并且对环境没有污染[6]。同时,酵母培养物还具有易存储、营养成分丰富多样、不易受外界因素影响等优点[5]。目前,酵母培养物主要采用固液发酵相结合的生产工艺,即利用液体培养基培养发酵菌种,接着使用固体培养基再进

表1 酵母培养物的主要组成成分[5]

Tab.1 Composition of yeast culture

酵母培养物主要成分 Yeast culture components	物质组成 Chemical substance
酵母细胞内容物 Yeast cell content	氨基酸、蛋白质、维生素、多肽以及核酸等营养性物质
变形培养基 Deformed culture medium	多肽、寡糖等营养性物质
酵母细胞外代谢产物 Extracellular metabolites of yeast cell	营养代谢产物(寡糖、有机酸、多肽)、芳香类物质(醇类、脂类)、酶类、增味类物质(核苷酸、多肽、氨基酸)以及未知营养因子等
酵母细胞壁 Yeast cell wall	β-葡聚糖、甘露聚糖等抗菌类物质

行发酵,经过干燥、灭菌而获得,其组成成分主要取决于发酵菌种、培养基配比和发酵工艺条件[7]。酵母培养物中不仅含有蛋白质、小肽和甘露寡糖,还含有少量枯草芽孢杆菌和活酵母细胞[8-10]。酵母培养物中的营养成分具有改善饲料适口性、提高动物生长性能、缓解氧化应激、提高机体免疫力和调节肠道菌群等益生作用,在畜禽生产中具有广阔的应用前景。如今,在"饲料端全面禁抗"的大背景下,开发高效、绿色的饲用抗生素替代物已成为饲料业的研究重点。因此,笔者综述了酵母培养物的生物学功能及其在畜禽生产中的应用,为其在畜禽生产中应用提供理论依据和数据参考。

1　酵母培养物生物学功能

1.1　抗炎及免疫调节

免疫系统包括先天免疫和适应性免疫系统。先天免疫系统由上皮屏障、白细胞(如巨噬细胞和中性粒细胞)以及分泌的细胞因子和补体等组成,是机体对入侵病原体最早启动的免疫反应[11]。若先天免疫系统无法控制感染,适应性免疫系统便被激活,通过T淋巴细胞、B淋巴细胞以及抗体等维持免疫系统平衡[12]。酵母培养物能够调节免疫防御体系,刺激动物的免疫反应,从而提高机体免疫力[13]。研究表明,酵母培养物中能增强免疫能力的主要活性物质是酵母细胞壁中的β-葡聚糖和甘露寡糖等。其中,β-葡聚糖与巨噬细胞和中性粒细胞的受体结合导致级联细胞因子和抗体的产生增加,从而增强巨噬细胞和中性粒细胞的功能[14]。来源于酿酒酵母细胞壁的β-葡聚糖能诱导Foxp3(+),LAP(+),GARP(+)T细胞的增加,可以延缓非肥胖型糖尿病小鼠血糖浓度的升高,通过细胞表面的模式识别受体树突状细胞相关性C型植物凝集素-1(Dectin-1)识别树突状细胞,诱导细胞因子白介素-10(interleukin-10,IL-10)、转化生长因子-β1(transforming growth factor-β1,TGF-β1)和白介素-2(interleukin-2,IL-2),以及产生吲哚胺2,3-双加氧酶,从而调节非肥胖型糖尿病小鼠的自身免疫[15]。β-葡聚糖还能与抗原递呈细胞的Toll样受体2(toll like receptor 2,TLR2)和Dectin-1结合从而增加L-selectin^{high} T细胞和$CD4^{+}CD25^{+}T_{reg}$细胞的数量,进而阻止I型糖尿病的发生[16]。口服β-葡聚糖还能诱导小鼠脾脏细胞中因化疗药物处理而被抑制的细胞因子干扰素-γ(interferon-γ,IFN-γ)和IL-2的表达,缓解其对小鼠脾细胞的毒性,从而有助于辅助治疗化疗药物引起的机体免疫抑制[11]。体外研究表明,β-葡聚糖还能增强巨噬细胞[17]、脾细胞[18]、嗜异性白细胞[19]的吞噬和杀菌能力。酵母细胞壁中的甘露寡糖也具有缓解炎症反应的潜力,其能够通过激活T淋巴细胞的分泌功能而调节机体的体液免疫反应。研究表明,酿酒酵母细胞壁甘露寡糖能够诱导巨噬细胞和嗜酸性粒细胞的增加,调控免疫反应,从而缓解高脂饮食诱导的炎症反应[12]。甘露寡糖能识别巨噬细胞表面的Toll样受体从而刺激其分泌白介素-12(interleukin-12,IL-12),进一步诱导免疫相关基因如TLR2、Toll样受体4(toll like receptor 4,TLR4)等的表达[20]。甘露寡糖自身也是一种抗原活性物质,能够激活机体的免疫应答及补体系统甘露寡糖结合凝集素激活途径,启动补体级联酶促反应,最终形成膜攻击复合物来调节免疫[21-22]。

1.2　抗氧化应激

氧化应激是由于体内生成的活性氧、氮化物和机体清除这些物质的能力之间的平衡失调所导致。研究表明酵母培养物可增加血浆超氧化物歧化酶、谷胱甘肽过氧化物酶和丙二醛的活性,从而提高机体抗氧化能力[23]。酵母自溶产物中含有较高含量的谷胱甘肽,同时具有较高的总抗氧化能力、二苯基苦基苯肼(2,2-diphenyl-1-picrylhydrazyl,DPPH)自由基清除能力、一氧化氮清除能力和羟基自由基清除能力,可作为新型天然抗氧化剂和免疫刺激剂用于功能性食品或药物[24]。体外研究发现,酵母培养物中的甘露糖具有较强的抗氧化能力,随着酵母甘露糖分子量的降低,其对Fe^{2+}、OH^{-}和O^{2-}的清除能力,以及对脂质过氧化的保护能力逐渐增强,同时这种效应还体现在保护氧化DNA的损伤方面[25]。此外,与维生素C的对比试验研究发现,酵母多糖中的甘露寡糖具有更强的DPPH清除能力[25],进一步研究证明,甘露寡糖的抗氧化功能是通过甘露糖基与细菌(如大肠杆菌*Escherichia coli*和沙门氏菌*Salmonella*)上的甘露糖基特异性受体结合,阻止致病菌与肠道的粘附,从而预防和减少机体感染几率[26]。

1.3　改善肠道屏障功能

正常生理状态下,肠道菌群处于动态平衡,各种细菌丰度在一定范围内维持相对稳定,然而一旦受到外界刺激,将这种稳定的动态平衡关系打破,便会引发肠道菌群失调。酵母培养物可在一定程度上重

塑菌群结构,维持肠道菌群平衡,保护肠道健康。酵母培养物在肠道中能与病原体竞争粘附位点,进而阻止其黏附定植于肠道[27],还可通过产生多种有机酸降低肠道pH值从而促进有益菌的增殖,抑制病原菌的生长,以维持机体消化道微生态平衡[28]。Kim等[29]研究发现在肉鸡日粮中添加1 g/kg酵母培养物,能优化回肠菌群结构,提高菌群多样性,提高厚壁菌门(Firmicutes)、乳酸杆菌(*Lactobacillus beijerinck*)和粪肠球菌(*Enterococcus faecalis*)的丰度。Shanmugasundaram等[30]研究表明,鸡感染球虫后,饲喂毕赤酵母细胞壁产物可减少其盲肠中的致病性沙门氏菌和大肠杆菌丰度,从而维持肠道健康。有研究显示酵母培养物能有效提高紧密连接蛋白*Occludin*、*Claudin-1*、*ZO-1*等的基因表达,其对肠道屏障的这一促进作用也归因于对肠道菌群的调控,深入分析发现酵母培养物能特异性提高益生菌乳酸杆菌的丰度,降低病原菌大肠杆菌和沙门氏菌的丰度,同时还有效地促进微生物代谢产物短链脂肪酸的产生[31-32]。

此外,酵母培养物影响肠道细胞因子介导免疫途径,通过调控肠道微生物群的变化进而维持微生态平衡。相关试验发现,日粮中添加酵母培养物可以通过抑制NF-κB相关通路抗炎因子的表达[33]和促进空肠和回肠*IL-10*的表达[34],从而缓解肠道炎症反应。在断奶仔猪日粮中添加酵母培养物可显著上调回肠*TLR2*、*TLR4*和*IL-10*的基因表达,说明酵母培养物可以调节Toll样受体和抗炎细胞因子,从而对肠道免疫屏障系统产生有益的影响,进而维护肠道屏障功能[34]。相同的研究发现,在断奶仔猪日粮中添加1,2,4 g/kg酵母培养物均可显著降低70 d仔猪空肠白介素-4(interleukin-4,IL-4)浓度,说明酵母培养物能增强Th1型免疫应答,对断奶仔猪肠道屏障功能有提高作用[35]。

2 酵母培养物在畜禽生产的应用

2.1 酵母培养物在反刍动物上的应用

2.1.1 调节瘤胃菌群结构 在奶牛生产中,酵母培养物可调节瘤胃菌群结构和内环境,改善瘤胃功能。体外试验发现,酵母培养物能够通过发酵活动[36]和改变纤维降解菌的生长活性[37]来稳定瘤胃pH,通过刺激瘤胃内乳酸利用菌的生长和增加微生物蛋白合成的方式,从而将过多的乳酸转变为短链脂肪酸,减少乳酸在瘤胃内蓄积,起到缓解瘤胃酸中毒的作用。此外,酵母培养物还具有促进纤维消化细菌生长的效果。体内试验发现,在饲喂低精料日粮的奶牛中添加15 g/d酵母培养物后,可以降低牛链球菌(*Streptococcus bovis*)的数量,而真菌和一些纤维素分解细菌(如假黄单胞菌*Pseudoxanthomonas*和产琥珀酸纤维杆菌*Fibrobacter succinogenes*)的数量增加,有利于降低瘤胃内乳酸浓度,从而降低亚急性瘤胃酸中毒的风险[38]。在妊娠期奶牛日粮中添加1.5%酵母培养物可以提高纤维分解细菌如瘤胃拟杆菌科(*Bacteroidaceae*)和螺旋藻(*Spirulina*)的数量,在瘤胃微生物协同作用下,促进纤维素的分解[39]。酵母培养物中的营养物质如氨基酸、肽、维生素和有机酸等还可为乳酸发酵菌(如埃氏巨型球菌*Megasphaera elsdenii*和反刍兽月形单胞菌*Selenomonas ruminantium*等)提供能量,以促进反刍动物的瘤胃发酵活动[2]。在调控肉牛瘤胃方面,Ogunade等[40]发现,在肉牛日粮中添加15 g/d活酵母产品可提高一些稀有纤维素消化细菌(沼泽红假单胞菌*Rhodopseudomonas palustris*)丰度,促进纤维素分解,从而达到调节瘤胃发酵的效果。在奶山羊的研究中,Stella等[41]发现饲粮中添加0.2 g/d酵母培养物可减少粪便中大肠杆菌的数量,增加乳酸杆菌数量,改善肠胃健康。

2.1.2 改善乳品质 在不同时期奶牛的体内试验均表明,饲粮中添加酵母培养物具有改善奶牛产奶量和乳脂水平的作用。项性龙等[42]发现,在荷斯坦牛高精料日粮中添加4%酵母培养物可以提高奶牛泌乳后期的产奶量、乳蛋白和乳脂肪含量。王卫正等[9]研究发现,在泌乳中期奶牛日粮中添加3%的酵母培养物,产奶量提高了1.42 kg/d,乳成分中乳脂率提高2.57%,乳蛋白率提高2.67%。同样,在早期泌乳奶牛日粮中添加300 g/d的酵母培养物可以显著提高乳脂率和乳蛋白率[10]。在奶山羊的研究中,Stella等[41]发现饲粮中添加0.2 g/d酵母培养物提高了泌乳前期奶山羊的产奶量。李海滨等[43]同样发现,日粮中添加25 g/d的酵母培养物可促进益生菌的增殖,显著提高奶山羊产奶量、降低料奶比。

2.1.3 缓解热应激 酵母培养物还表现出较强的缓解奶牛热应激的作用。在热应激条件下,泌乳早期奶牛日粮中添加1.0 g/d酵母培养物可提高能量校准乳(ECM)产量,且干物质采食量(DMI)不受影响,干物质转化ECM的效率提高7.4%[44]。汤志宏等[45]在日粮中添加100 g/d酵母培养物,显著提高了热应激奶牛的产奶量、瘤胃氨态氮水平、微生物蛋白浓度、粗蛋白和中性洗涤纤维的表观消化率,缓解了热应激对

奶牛生产性能的不利影响。此外,Julia等[46]研究发现,日粮中添加15 g/d酵母培养物可提高奶牛的抗热应激能力、降低奶牛直肠温度、呼吸速率和皮肤温度。

酵母培养物在反刍动物生产中的大量应用实践证明,酵母培养物一方面是通过提高纤维分解细菌的数量促进纤维素的分解,从而调节瘤胃内菌群结构改善瘤胃发酵模式,另一方面改善营养物质的消化吸收、增加产奶量与乳脂水平来提高生产性能,最终获得更优的养殖生产效益。

2.2 酵母培养物在猪上的应用

2.2.1 提高生长性能 近年来,酵母培养物作为饲料添加剂已广泛应用于猪的生产中,对猪的生长性能、营养物质消化吸收以及繁殖性能等方面都具有积极作用[34]。Waititu等[47]发现,日粮中添加酵母培养物可通过改善营养物质的消化吸收来提高猪生长性能。郭小华等[48]研究发现在断奶仔猪日粮中添加0.5%酵母培养物可以降低仔猪腹泻率,显著提高断奶仔猪的日增重和日采食量。此外,向仔猪日粮中添加酵母培养物还能增加粪便中乳酸菌的数量,促进干物质营养消化吸收,提高仔猪生产性能[49]。酵母来源的β-葡聚糖与牛酪蛋白水解物配伍添加于仔猪日粮中,能够通过抑制NF-κB信号通路来维持仔猪肠道健康,提高粪便健康评分以及生长性能[50]。另外,酵母培养物的代谢产物小肽可减少断奶仔猪肠道内大肠杆菌和沙门氏菌的繁殖,促进断奶仔猪肠道内有益菌属乳酸菌的增殖,调节肠道微生物群,并提高生长性能[51]。

2.2.2 改善肠道屏障功能 仔猪在断奶阶段,消化道发育尚未健全,日粮和环境的改变,使仔猪极易受到病原菌感染,发生肠道屏障受损及肠道炎症,酵母培养物作为一种发酵型物质,可以改善肠道形态、维持肠黏膜完整性,对维持动物肠道健康有积极意义[5]。酵母培养物可通过为共生菌提供底物调节肠道菌群代谢活动,改变菌群结构,增强肠道屏障功能,最终促进肠道健康。相关试验发现,在断奶仔猪日粮中添加2%酵母培养物,可显著提高日增重,并通过增加肠上皮细胞和巨噬细胞的数量以改善肠道结构,进而维持肠道健康[52]。郑文涌等[53]研究发现日粮中添加5%酵母培养物可增加肠道菌群多样性,并对肠道屏障和发育产生积极作用,改善肠道菌群组成和稳定性。Shen等[54]在断奶仔猪日粮中添加5 g/kg酵母培养物,可显著提高仔猪的空肠绒毛高度、绒毛高度与隐窝深度比值,同时调节机体免疫应答反应,从而增强肠道屏障功能,这与李玉欣等[55]研究毕赤酵母甘露寡糖对断奶仔猪生产性能肠道绒毛和细胞因子的影响结果相同。此外,其进一步研究发现,毕赤酵母甘露寡糖还有助于提高肠道杯状细胞数量,从而促进杯状细胞的分泌物黏蛋白和三叶肽的分泌,这些物质分泌量增加会对肠道的稳定性和完整性起到保护作用。

2.2.3 提高繁殖性能 酵母培养物对母猪和公猪也有一定的益生作用。在哺乳母猪分娩前,由于机体产生应激,出现体内激素不断变化和营养物质代谢紊乱的现象,营养物质的代谢异常会降低母猪繁殖性能[56]。吴泽等[57]研究发现,妊娠期添加0.5%酵母培养物显著降低初产母猪血浆中总胆固醇和低密度脂蛋白含量,表明酵母培养物可能通过调节体内低密度脂蛋白含量,改善肝脏内源胆固醇合成,进而改善母猪哺乳期脂类代谢过程,减少体脂动员,提高利用年限。陈鹏等[58]发现,在母猪日粮中添加不同水平酵母培养物(妊娠期0.5%、哺乳期0.8%),可提高平均窝增重23.48%,断奶窝重19.2%,同时也降低母猪发情的时间间隔。梁秀丽等[59]在公猪日粮中添加5 g/kg酵母培养物,显著提高公猪的精液量、精子密度和精子活力,并显著降低精子的畸形率。

酵母培养物作为酵母类饲料产品,可通过改善肠道屏障功能、改变肠道菌群结构和促进营养物质消化吸收以提高仔猪的生长性能,还可通过降低母猪的发情间隔和提高公猪的精液质量,从而提升猪的繁殖性能。

2.3 酵母培养物在鸡上的应用

2.3.1 增强机体免疫功能,提高抗病能力 Zhou等[60]发现1 g/kg酵母细胞壁多糖的添加量能够通过增加蛋鸡血清中免疫球蛋白M(immunoglobulin M,IgM)水平和回肠β-防御素的表达提高机体免疫力,同时还能缓解脂多糖(lipopolysaccharide,LPS)诱导的血清白介素-6(interleukin-6,IL-6)、白介素-1β(interleukin-1β,IL-1β)和回肠IL-6、IL-1β、肿瘤坏死因子-α(tumor necrosis factor-α,TNF-α)和IFN-γ增加。网络关联分析进一步发现,酵母细胞壁多糖发挥免疫调控作用与肠道菌群的变化具有强相关性,可以通过促进益生菌如双歧杆菌(*Bifidobacterium*)、乳酸菌(*Lactic acid bacteria*),以及病原菌抑制志贺氏菌(*Shigella*)而发挥益生作用。朱春霞等[61]研究基础日粮、抗生素日粮、酵母培养物对肉鸡生长及抗病性能的影响,结果表明酵母培养物组肉鸡的日增重和日采食量较对照组均有一定的提高,料肉比、发病率、死亡率和淘汰率均有所降低。在肉鸡日粮中添加不同发酵时间的酵母培养物,结果发现,其均能显著或极显著提高21 d

肉鸡血清中总蛋白含量,促进肉鸡蛋白质的代谢,提高其对蛋白质的吸收和利用,进而促进组织器官生长,显著改善肉鸡的免疫性能[13]。在肉鸡日粮中添加4 g/kg酵母培养物可以提高肉鸡的免疫功能,血液中B淋巴细胞、T淋巴细胞数量均相应减少[62]。为评估酵母培养物对免疫应答的影响,研究者对脾脏和法氏囊等免疫器官也开展了相关研究,Attia等[63]研究发现,酵母培养物可提高胸腺和法氏囊的相对重量,法氏囊的卵泡直径变大,通过影响巨噬细胞的激活、抗体合成和免疫器官的重量来调节机体的免疫反应。

2.3.2 增强抗氧化能力 研究发现,向1 d肉鸡日粮中添加1 g/kg酵母细胞壁,经过35 d试验期发现肉鸡肠道绒毛高度、杯状细胞数量及黏液层厚度显著增加,还提高了肠道消化酶如乳糖酶、麦芽糖酶和碱性磷酸酶的活性,增强肠道屏障的完整性,同时显著降低促炎性细胞因子IL-1β、IL-12和IL-18的水平[64]。酵母培养物和酶水解酵母细胞壁配伍使用在肉鸡日粮中能够有效提高空肠超氧化物歧化酶(superoxide dismutase,SOD)和谷胱甘肽过氧化物酶(glutathione peroxidase,GSH-Px)的活性,降低丙二醛(malondialdehyde,MDA)的浓度,同时增加空肠中抗氧化通路相关基因*Nrf2*、*SOD1*、*HO-1*和*GPX1*的表达量[65]。日粮中添加0.9%~1.2%酵母培养物能提高肉仔鸡血清抗氧化能力,降低腹脂率,以及减少胸肌滴水损失,并且显著提升肉仔鸡血清GSH-Px、SOD和总抗氧化能力(total antioxidant capacity,T-AOC)的活性,有效调控肉仔鸡的抗氧化能力[66]。此外,Ogbuewu等[67]发现酵母培养物中的β-葡聚糖和甘露寡糖还可通过改善肠黏膜结构及促进锌、硒、铜等营养元素的吸收,从而提高抗氧化性能。

2.3.3 改善蛋品质 Zhou等[60]发现添加1 g/kg酵母细胞壁多糖能够增加蛋鸡的饲料转化率和产蛋量。Liu等[68]也发现,向蛋鸡日粮中添加2 g/kg酵母培养物,能有效提高蛋品质和产蛋率。Araujo等[69]发现在种蛋鸡日粮中添加0.3%酵母培养物可提高产蛋率(2.14%),以及孵化蛋和可育蛋的孵化率(4.79%和2.56%)。而张嘉琦等[70]研究发现,在蛋鸡日粮中添加0.4%和0.6%酵母培养物对产蛋率无显著影响,但可显著改善蛋壳厚度和蛋黄比率,并通过提高饲料转化率来改善蛋鸡的生产性能。这也表明了不同类型的酵母培养物添加剂量及作用效果有差异,应当根据菌种、剂量等在蛋鸡生产中合理使用,其具体的机理有待进一步的研究。

酵母培养物可以调节机体免疫功能、改善机体血液生化指标、提高鸡的生长性能。日粮中添加酵母培养物可提高肉鸡的平均日增重和免疫力,调节机体免疫功能、改善机体血液生化指标、降低饲养成本的同时促进鸡只的生长;在蛋鸡上使用能提高产蛋率、减少死淘率,延长产蛋高峰期,提高产蛋鸡的生产性能和经济价值。

3 小结与展望

酵母培养物作为一种新型饲料添加剂,具有抗氧化、抗炎、增强机体免疫力、改善肠道屏障功能等生物学功能。综合酵母培养物在不同畜禽上的研究,发现酵母培养物可提高生长性能、缓解热应激及调控肠道屏障功能等,能有效改善畜禽健康状况,在畜牧业中具有巨大潜力和应用前景。然而,目前现有的酵母培养物产品质量参差不齐,在畜禽生产中的应用效果高低不一,严重限制其作为新型饲料添加剂的应用及推广。因此,今后应重点针对筛选酵母菌、开发不同畜禽酵母培养物应用品种以及配套饲喂方式等方面开展深入研究,开发性能稳定、作用效果优越的酵母培养物产品。

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