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改善产蛋后期鸡蛋蛋壳质量研究进展

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摘　要: 蛋壳质量是评价蛋品质的重要指标,和鸡蛋的运输和保存过程中的破损率相关,且直接与种蛋的合格率、孵化率和鸡苗的健康密切相关,是影响蛋鸡生产效益的要素之一。蛋鸡老龄化是导致产蛋后期蛋壳质量下降的主要因素。特别是近年来,商品蛋鸡的产蛋周期大大延长,蛋鸡老龄化程度更高,这导致产蛋后期面临的蛋壳质量下降的问题更为严峻。本文对蛋壳的形成过程和钙代谢过程引起产蛋后期蛋鸡蛋壳质量下降的原因进行了概述,并对提高产蛋后期蛋壳质量的调控措施进行了总结和展望。

关键词: 蛋鸡;产蛋后期;蛋壳质量;子宫衰老;钙代谢
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蛋壳质量问题一直是蛋鸡养殖业关注的重点,该问题通常会导致鸡蛋在收集、储存和运输过程中存在10%~15%的破损率[1],直接影响经济效益。特殊时期(比如产蛋初期和产蛋后期)或特殊状况(比如疾病、应激、换料等)下,蛋壳质量降低会导致鸡蛋在收集、储存和运输过程中破损率更高;对蛋(肉)种鸡来说,蛋壳质量的下降还严重影响种蛋合格率和孵化性能(如孵化率和健雏率等)。蛋壳质量包括蛋壳比重、蛋壳强度、蛋壳厚度、相对密度、单位表面积的壳重和蛋壳变形值等评价指标,受到蛋鸡品种、日龄和饲养方式以及鸡蛋的贮存条件等因素的影响[2-3]。蛋壳主要是由碳酸钙组成,故蛋鸡的钙代谢水平会直接影响蛋壳的质量。值得特别关注的是,产蛋后期鸡蛋的蛋壳质量显著低于初产后期和高峰期。因此,蛋鸡的日龄被认为是影响蛋壳质量的主要因素之一[4-5]。

产蛋后期鸡蛋的蛋壳质量显著下降是蛋鸡养殖过程中面临的重要问题。特别是近年来,为了更好地利用鸡舍设备、降低生产成本,家禽养殖业提出延长蛋鸡和种鸡(包括肉种鸡和蛋种鸡)淘汰周龄的方案,即将淘汰周龄从传统意义上的72周龄延长至80周龄,甚至延长至100周龄。因此,改善产蛋后期的蛋壳质量成为研究热点,亦成为科学难题。为解决这一科学难题,研究者们和蛋鸡养殖从业者们通常将目标锁定在品种改良和提高饲粮营养水平上,以期改善产蛋后期蛋壳质量。然而,从遗传角度实现蛋鸡品种改良已进入一个瓶颈期。由于蛋鸡产蛋性能的高度开发、产蛋期蛋鸡的生理特性特殊,“产蛋后期蛋壳质量下降”这一难题已经无法继续通过育种解决,而从营养学的角度加以改善则成为可能。改善产蛋后期蛋壳质量对蛋鸡养殖具有重要意义,本文对蛋壳的结构和形成过程、蛋鸡衰老对蛋壳质量的影响、产蛋后期蛋鸡钙代谢的改变以及提高产蛋后期蛋壳质量的措施进行了综述。

1　蛋壳的结构和形成

1.1　蛋壳超微结构与蛋壳质量的关系

蛋壳是鸡蛋的保护屏障,不仅维持着鸡蛋的形态,同时可以抵御外界的污染。蛋壳主要由约95%的碳酸钙和3.5%的有机基质蛋白质组成,其

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中碳酸钙组成的方解石晶体占整个蛋壳重量的 94%~97%[6]。在扫描电镜的观察下,可将蛋壳的超微结构由内而外划分为壳膜、乳突层、栅栏层、晶体层和角质层[7](图 1)。

乳突层和栅栏层的状况对蛋壳质量影响较大,研究表明,乳突层和栅栏层中方解石晶体的平均尺寸、形状和取向对蛋壳的力学特性有一定的影响[8-9],例如方解石晶体的平均尺寸减小有助于提高蛋壳强度[10]。乳突层的密度、乳突节的宽度、栅栏层的厚度与蛋壳的强度也密切相关,一般来说,乳突层的密度越大、乳突节越小、栅栏层越厚,蛋壳强度越高[11-13]。相比于乳突层,栅栏层的厚度占蛋壳总厚度的 2/3,对蛋壳质量的优劣影响更大,栅栏层也被称为蛋壳的有效厚度[14-15]。

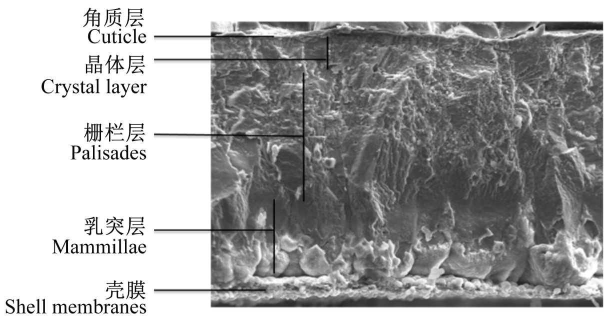


图 1　蛋壳结构扫描电镜示意图

Fig.1　Scanning electron microscope diagram of eggshell structure (400×)

1.2　蛋壳的形成过程

蛋壳形成在输卵管远端的子宫部部位,经过 10~22 h 的矿化过程形成完整的蛋壳结构,即鸡蛋形成过程中大部分时间用于形成蛋壳。蛋壳形成的过程主要包括乳突层成型、栅栏层线性矿化、角质层终止反应等阶段,最终形成高度有序的矿化结构,这是已知速度最快的生物矿化过程[16-17],其中乳突层和栅栏层的碳酸钙形成是矿化时的关键环节,子宫部内矿化过程的状态也直接决定蛋壳质量的优劣。

蛋壳方解石中的碳酸钙前体主要来源于血液中的二氧化碳(CO_2)和钙离子(Ca^{2+})[16]。矿化开始时,血液中的 CO_2 通过子宫部腺体细胞膜的简单扩散渗透到细胞内,在关键酶——碳酸酐酶(CA)的催化下,和水发生反应生成碳酸氢根离子(HCO_3^-)并被分泌到子宫部液中[7,18]。血液中的 Ca^{2+} 也通过子宫部腺体细胞转运至子宫部液中,和 HCO_3^- 结合反应形成碳酸钙,并迅速在鸡蛋软壳膜表面逐渐沉积形成方解石晶体[19]。矿化过程中 Ca^{2+} 的输出非常迅速,相当于每 12 min 消耗 1 次血浆总钙[20],该过程还需要不断通过骨溶解提供 Ca^{2+} 来满足蛋壳对钙的需要[21]。无论饲粮中的钙水平是否满足蛋壳的成型,蛋鸡都会从骨骼中调动 Ca^{2+} 提供给蛋壳,故骨骼钙代谢与蛋壳的形成也是密切相关的[22]。

研究表明,鸡蛋的重量和体积会随着日龄的增长而增长,但蛋壳的重量不会随着日龄和蛋的体积的增长产生较大的波动[23-24]。这一现象说明,每枚鸡蛋形成过程中蛋壳的总质量是相对稳定的,伴随产蛋鸡日龄的增长,蛋壳的厚度会呈现逐渐降低的趋势[25-26](图 2),这也说明产蛋初期和高峰期的蛋壳质量往往要优于产蛋后期的原因。综上所述,产蛋后期蛋壳质量的下降,可能是由于蛋壳的乳突层和(或)栅栏层的厚度发生了变化,影响了整体的蛋壳力学特性、变形值和强度;或是由于骨钙和壳钙沉积比例失衡影响了蛋壳的钙沉积,从而导致构成蛋壳的组分比例发生了变化,这二者都可能与衰老造成的子宫部机能退化有关。

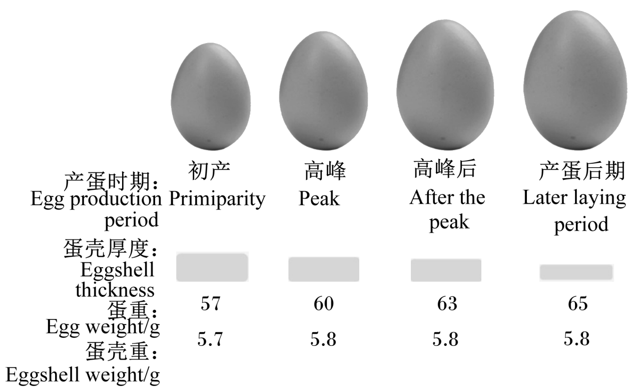


图 2　随日龄的增长鸡蛋的蛋壳厚度和蛋重变化示意图(以海兰褐蛋鸡所产鸡蛋为例)

Fig.2　Variation diagram of eggshell thickness and egg weight with days of age (take the eggs of the Hy-Line Brown laying hens for example)

2　子宫部衰老对蛋壳质量的影响

2.1　子宫部的衰老

禽类子宫部被称为"蛋壳腺",当鸡蛋进入子宫部时,子宫部会快速分泌子宫部液。子宫部液中没有细胞,但包含构成蛋壳的所有无机前体(钙

和碳酸氢盐)和有机前体(形成蛋壳基质的蛋白质等)[27-28]。一般情况下,将 40 周龄界定为蛋鸡开始衰老的时间[17],经过长期选育,蛋鸡的生产周期大大延长,但同时也使得蛋鸡更加趋于老龄化,造成产蛋后期器官损伤和功能退化等问题更加突出,例如肠道功能的降低、输卵管的萎缩和炎症等亚临床病症。长期的产蛋行为造成子宫部的松弛、内膜炎症和内膜萎缩,伴随子宫部内膜形态发生变化、子宫部纤毛长度增加和性腺激素分泌逐渐减少,造成子宫部内膜细胞的再生能力下降,故子宫部内膜细胞的状态被认为是影响蛋壳质量的主要因素之一[16,25]。此外,商品化高产蛋鸡由于长期持续的产蛋行为引起的慢性刺激,可能加剧了子宫部内膜的纤维化和萎缩[29],比普通家养品种更早出现子宫部损伤和机能衰退,产蛋后期的蛋壳质量下降也更早地表现出来。

2.2 子宫部衰老对蛋壳质量的影响

随着产蛋后期蛋鸡子宫部内膜细胞的再生能力下降、子宫部液分泌不足、矿化过程异常,蛋壳钙沉积均一度发生异常,影响了蛋壳的厚度和均一性,降低了蛋壳强度[30],这可能造成生产中出现钙斑蛋、沙壳蛋、畸形蛋和破壳蛋等。此外,子宫部衰老还会造成蛋壳的变形值和蛋壳比重等指标也出现下降[31]。单纯的蛋壳厚度测量不足以对蛋壳的力学性能进行评价[1],厚度相同的蛋壳可能蛋壳质量并不相同,需要从更微观的结构观察来揭示蛋壳质量异常的原因。鸡蛋进入子宫部后,子宫部液中的无机盐和有机基质依次在壳膜沉积,先是乳突层逐渐增高,再到栅栏层的碳酸钙堆积,最后角质层结晶标志着蛋壳的成型[12,29]。当子宫部内膜萎缩、子宫部液分泌异常时,可能会导致这些蛋壳前体的沉积出现异常。研究发现,随着蛋鸡老龄化,蛋壳栅栏层厚度显著降低、蛋壳透明度增加、乳突层融合度降低、角质层覆盖率下降[32-34]。这可能是由于子宫部衰老影响了子宫部上皮中各类离子通道和子宫部液的基质蛋白质分泌造成的[28-29],尤其是当 Ca^{2+} 的输入异常时,碳酸钙沉积顺序紊乱,导致蛋壳质量下降[35]。

3 钙代谢对产蛋后期蛋壳质量的影响

3.1 肠道吸收钙的能力下降

饲粮是蛋鸡钙的主要来源,通过消化吸收作用,进入体液,由体循环运送至钙沉积的主要组织(图 3)。肠道黏膜钙吸收途径主要包括跨细胞途径和旁细胞途径。跨细胞途径是一个主动转运的过程,依赖于 1,25-二羟基维生素 D_3 [1,25-$(OH)_2D_3$]的调节,主要发生在十二指肠;旁细胞途径则是一个浓度依赖性的离子扩散过程,可以发生在整个肠段[36]。通过旁细胞途径过程来吸收钙需要肠腔内游离的 Ca^{2+} 达到一定的浓度(2~6 mmol/L),才能克服由跨膜电位差和 Ca^{2+} 浓度差组成的屏障,该细胞途径能够吸收的钙与肠道管腔的钙浓度直接相关[37-38]。肠道不同的部位对钙吸收的贡献不同,就哺乳动物而言,虽然十二指肠的主动转运过程很活跃,但大部分钙的吸收发生在回肠中[39-41]。在禽类中,大部分钙在到达回肠之前就被吸收,这可能与禽类近端肠道的 Ca^{2+} 吸收效率较高和回肠段的电位差较低有关[42]。钙在蛋鸡肠道中的吸收受多种因素调控,例如饲粮中的钙浓度[43]、维生素 D_3 浓度[44]、饲粮颗粒大小[45]、蛋鸡日龄[46]等。在饲粮成分不变的情况下,日龄成为影响蛋鸡钙吸收的主要因素,产蛋后期的蛋鸡肠道对钙的消化吸收能力下降,进而可能造成蛋壳质量下降[22,47]。关于产蛋后期蛋鸡肠道对钙的吸收能力下降的相关研究很少,且未见机制报道,还需深入探索。

3.2 组织转运钙的能力减弱

商品化蛋鸡在产蛋期间需要大量的钙,每天用于产蛋的钙量大概为全身钙量的 10%,差不多相当于 1 枚蛋壳的重量[48]。蛋壳矿化期间摄入的钙元素远远不能满足生成蛋壳的需要,所以大部分钙都需要机体重新利用,这期间机体大部分游离钙被肾脏重吸收,钙的排出量基本为 0[49]。这些被重吸收的 Ca^{2+} 将通过一系列的钙转运载体,经体液循环运送至子宫部、髓质骨或其他组织部位(主要运输至子宫部)。Ca^{2+} 转运载体在肾脏、子宫部、肠道这些钙转运活跃的器官和组织中广泛表达,包括钙结合蛋白(Ca-binding protein,CaBP)、质膜钙泵(plasma membrane calcium ATPase,PMCA)和上皮细胞钙离子通道——瞬时感受器电位香草酸受体(transient receptor potential vanilloid,TRPV)[50-51]。这些钙转运载体可以协助 Ca^{2+} 通过体液循环向子宫部、血液和骨骼等部位快速转运,它们的表达量在一定程度上反映出钙代谢能力的强弱。研究表明,提高钙的补充量能引起 45 周龄后来航鸡子宫部内 *CaBP-D28k* 的 mRNA水平的提高,增加蛋壳的钙沉积,相应地提

高蛋壳的强度[52]。还有研究报道,75 周龄的海兰褐蛋鸡,*CaBP-D28k* 和 *PMCA* 的表达量减少,导致 Ca^{2+}的转运显著减少,进而导致子宫部内蛋壳钙的沉积产生紊乱,蛋壳表面沉积的钙减少,最终导致暗斑蛋的产生,并对蛋品质产生严重的影响[53]。TRPV6 主要在子宫部中分布广泛,*TRPV*5 在肾脏中表达较高,矿化开始时,*TRPV*6 在子宫部的表达活跃,对于蛋壳早期钙的沉积至关重要,可能影响乳突层和栅栏层的形成[54-55]。产蛋后期蛋鸡对钙的需求量更大,研究表明,71 周龄的海兰褐蛋鸡肠道 *CaBP-D*28*k* 和肾脏 *PMCA* 的表达降低,子宫部中的 *CaBP-D28k* 和 *PMCA* 的表达也均发生下降,这些钙转运载体表达量的减少可能间接造成蛋壳质量的下降[56-57]。

3.3　钙的沉积方向改变

髓质骨是禽类的特殊结构,也是产蛋鸡的“钙库”。在日间,鸡蛋蛋壳的钙来源于肠道的吸收和髓质骨的分解;在夜间,由于光照停止,蛋鸡不再进食,髓质骨要提供更多的钙以供蛋壳形成。母鸡达到性成熟后,即从开产前 2 周开始,其骨骼在生物学上会发生巨大的形态变化,从长骨(胫骨、肱骨和股骨)骨干的内膜面形成大量向骨髓腔突出的网织状小骨针,称为髓质骨[58-59]。在雌激素的作用下,髓质骨不断分解,大概以 1.6 g/d 的速度提供 Ca^{2+}给蛋壳,直到产卵期结束,这一过程被称为“融骨”[60]。在矿化以外的时间,蛋鸡摄入的钙元素会随着体液循环主要储存在髓质骨中,以供产蛋时使用。一般状况下,蛋壳形成期主要在夜间,机体需要提供 2.0~2.5 g 钙才能合成 1 个蛋壳,夜间停止光照过程中蛋壳有 25%~40%的钙是通过髓质骨的融骨作用获得[61]。

随着母鸡的衰老,骨形成过程(成骨细胞)和骨吸收过程(破骨细胞)之间出现负平衡,髓质骨会明显扩张,而结构骨(松质骨和皮质骨)受到损伤[17]。特别是伴随着蛋鸡衰老导致的钙的吸收利用率降低,饲粮中吸收的钙不足以支撑蛋壳的形成,结构骨的损失会更加严重。此时,蛋鸡结构骨的数量逐渐减少,导致骨骼脆弱,极易患上骨质疏松,严重影响母鸡的健康和福利。据报道,约 30%的蛋鸡在产蛋后期因骨折而被淘汰,造成了巨大的经济损失[18,61-62]。产蛋后期蛋鸡髓质骨在骨腔内的扩张是不可避免的,来自骨组织提供给蛋壳的钙比例将越来越高,而来自饲粮中的钙所占比例逐渐降低,这将直接影响蛋壳质量和产蛋量。研究表明,产蛋后期骨质疏松的蛋鸡子宫部中部分钙转运载体(*CaBP-D*28*k*、*PMCA*)的表达量下降[63],这可能会间接影响蛋壳的质量。解决产蛋后期蛋壳质量下降的问题,需要从提高钙代谢能力的方向出发,强化钙的吸收与利用,减缓蛋壳钙沉积异常的负面影响。产蛋后期蛋鸡体内的钙代谢方向大致可概括为图 3。

4　改善产蛋后期蛋壳质量的营养调控措施

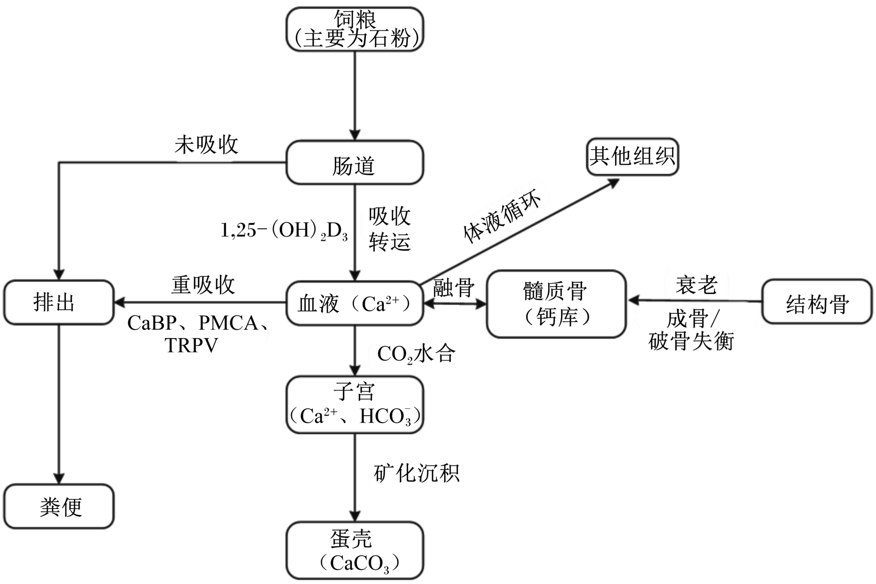
4.1　添加雌性激素

1,25-$(OH)_2D_3$ 是促进肠道钙吸收的关键因子,在维持体内钙稳态、影响骨骼发育等方面发挥重要作用,是维生素 D 通过在肝脏、肾脏中连续转化形成的活化状态,其活化受到机体雌性激素水平的影响。在蛋鸡饲粮中外源添加 1,25-$(OH)_2D_3$通常难以利用,可通过添加外源性雌性激素影响 1,25-$(OH)_2D_3$ 的生成。黄体酮和雌二醇具有调控子宫部内膜 Ca^{2+}转运蛋白表达的作用,并且可以促使蛋鸡饲粮中的维生素 D 吸收代谢产生足够的 1,25-$(OH)_2D_3$[64-66]。研究发现,黄体酮能够提高 45 周龄海兰褐蛋鸡的蛋壳栅栏层比例,进而提高了蛋壳的厚度和强度[67]。而雌二醇可以通过促进机体对钙的吸收(部位)来提高钙在 70 周龄罗曼褐蛋鸡蛋壳的沉积,进而提高蛋壳的强度和厚度[68]。一些在哺乳动物上的研究也报道了雌性激素能是通过影响子宫中降钙素的表达、肠道(*TRPV*6 和 *PMCA*)和肾脏(*PMCA*)中的钙离子转运蛋白的表达来调节钙代谢[69-72]。在禽类中,雌性激素(雌二醇)可能是通过促进维生素 D_3 的合成提高肠道钙离子转运蛋白(*CaBP-D*28*k*)的表达[73]、或者通过调节肾脏中甲状旁腺素受体促进对 Ca^{2+}的重吸收来调节钙代谢[74]。总之,补充雌性激素能够促进钙的吸收,提高产蛋后期的蛋壳厚度和蛋壳强度,从而达到改善蛋壳质量的目的[75-76]。

4.2　添加微量元素

微量元素参与了蛋鸡的生长和发育,包括蛋壳和骨头的形成,它们不仅是蛋壳合成相关酶的活化剂或组分,而且可以在蛋壳形成过程中直接与碳酸钙晶体相互作用,从而影响蛋壳的质量[77-79]。锌、锰、铜是蛋鸡重要的微量元素,不仅维持着生命的基本活动,还对蛋壳的质量有一定的影响。研究表明,在饲粮中添加锰促进了蛋壳膜中糖胺聚糖的合成,改善了蛋壳的乳突层和栅

栏层,提高了 50 周龄海兰褐蛋鸡的蛋壳强度、厚度和韧性[80]。锌是 CA 的一个组成部分,而 CA 负责催化 CO_2 和水形成 HCO_3^-,直接影响着碳酸钙晶体的形成[79]。添加锌能够提高 68 周龄来航鸡和 64 周龄褐色蛋鸡的蛋壳厚度[81-82]。铜也具有提高蛋壳质量的作用,在饲粮中添加适当剂量铜可以提高 106 周龄的尼克蛋鸡的蛋壳重量[83]。总之,锌、锰、铜这 3 种微量元素都能够起到改善蛋壳超微结构、提高蛋壳质量的作用[84]。此外,研究还发现,用有机微量元素代替无机微量元素对产蛋后期蛋鸡蛋壳质量的改善效果更佳,改善了 50 周龄后的海兰褐蛋鸡蛋壳的超微结构,提高了蛋壳强度[85]。将饲粮中的氧化锌替换为锌-氨基酸螯合物能提高蛋壳强度、蛋壳重量和蛋壳厚度[86];用有机锰(氨基酸螯合锰或锰蛋白)替代无机锰同样也能起到更好地改善蛋壳超微结构,提高蛋壳厚度和强度的作用[87-88]。



1,25-(OH)$_2$D$_3$:1,25-二羟基维生素 D$_3$ 1,25-dihydroxyvitamin D$_3$;CaBP:钙结合蛋白 Ca-binding protein;PMCA:质膜钙泵 plasma membrane calcium ATPase;TRPV:瞬时感受器电位香草酸受体 transient receptor potential vanilloid。

图 3 蛋鸡钙代谢示意图

Fig.3 Schematic diagram of calcium metabolism in laying hens

4.3 添加植物提取物

随着"禁抗令"的出台,寻找抗生素替代品成为近年来的热门话题,植物提取物能够提高生产性能,且具有对环境友好的特点,在养殖行业被大力开发。研究报道,一些以中草药制剂为主要来源的植物提取物具有提高蛋鸡的蛋壳重量、蛋壳厚度、蛋壳表面积的作用[89]。Ding 等[90]在 54~65 周龄罗曼蛋鸡饲粮中添加一种商业化的植物精油混合物,发现当添加量为 50 mg/kg 时其有增加蛋壳厚度和蛋白质消化率的趋势。Mousavi 等[91]在饲粮中添加 200 mg/kg 的草本植物精油混合物(百里香、薄荷、迷迭香和茴香),也提高了 40 周龄后的海兰褐蛋鸡的蛋壳强度和厚度。许多单一植物提取物也被报道能够提高蛋壳质量,如红三叶草提取物和大蒜提取物在浓度为 0.1%时可以提高 30 周龄后 Boris 褐蛋鸡的蛋壳厚度和强度[92],添加 100 mg/kg 的薄荷提取物可以提高 40 周龄后的罗曼蛋鸡的蛋壳强度[93],迷迭香(250 mg/kg)、菊粉(1 g/kg)等提取物等也具有提高蛋壳厚度和强度的作用[94-95]。这些植物提取物都可以起到提高产蛋后期蛋鸡生产性能、改善蛋壳质量的作用,无疑在禁抗的大环境下为畜牧业提供了诸多选择。

4.4 改进饲喂模式

钙作为蛋壳沉积的核心元素,很容易被认为添加量越高,蛋壳品质越好。然而,有研究表明,钙含量只有在低于2.5%时才会与蛋壳质量间存在线性关系,超过这个含量时各浓度间并未出现显

著差异[96]。蛋鸡对钙的吸收能力有限,盲目增加饲粮中的钙含量并不能改善蛋壳质量[97],反而会增加蛋鸡消化道的负担,引起对其他微量元素的拮抗作用[98],有研究报告,钙含量过高会导致锌的利用率降低[99-100]。因此,寻找提高饲粮中钙的利用率的方法比单独增加饲粮中钙含量对蛋壳质量的改善更为有效。

动态饲喂(dynamic feeding)是最近新兴的一种饲喂方式,指的是不改变饲粮配方的条件下,按照动物代谢的规律,在不同时间点饲喂不同量的饲粮,提高饲粮利用率,从而达到节省饲粮的目的。Liu 等[101]采用动态饲喂的模式,于 07:30 和 15:30 2 个时间点进行饲喂,提高了 41 周龄后的海兰褐蛋鸡的肠道吸收能力,这可能是由于动态饲喂改变了肠道生物钟基因的表达;Lin 等[102]采用相同的饲喂模式饲喂不同钙含量的饲粮,发现钙的可用性得到了提高。在此基础上,笔者调整了饲喂方式,按照原来的饲粮配方,将 08:00 和 14:00 各饲喂 1/2 饲粮改为上午 1/3 和下午 2/3,发现能够极显著降低 78 周龄的海兰褐蛋鸡的料蛋比,提高蛋壳强度和蛋壳厚度;且采用动态饲喂的模式使用钙含量低的饲粮,蛋壳质量也并未下降,表明动态饲喂的模式可以提高钙的可用性。在不改变饲粮原本配方的情况下,改进饲喂方式是相对经济、环保、健康的方式,动态饲喂模式符合这些特点,其不仅有益于蛋鸡的健康,而且有提高钙的利用率的潜能,值得进一步探索。

5　小　结

蛋鸡的衰老必然引起产蛋率下降、蛋壳质量降低和骨质疏松等问题,从而造成生产效益的下降。其中,蛋壳质量下降导致的蛋壳易碎是当今蛋鸡行业最关注的问题。蛋鸡老龄化会引起子宫部的衰老和蛋鸡钙代谢的改变,影响蛋壳的超微结构,造成蛋壳质量的下降。补充雌性激素、微量元素、有机酸等添加剂能够在一定程度上缓解产蛋后期蛋壳质量的下降,但也需要考虑可能随之而来的其他问题,比如外源性雌性激素可能会导致内分泌紊乱、脂代谢平衡失调,微量元素对环境具有一定的的潜在风险。植物提取物作为抗生素替代品具有一定的潜能,但生产成本较高、技术尚不成熟。针对提高蛋壳质量的研究已有较多成果表明营养添加剂的方式能够起到有效作用,受成本、工艺等因素的影响,短期内只有少量产品可以用于蛋鸡养殖业中的规模化生产,还需持续探索。而传统的饲喂模式近年来并未发生重大改变,对于饲喂模式的研究相对空白,例如本文提及的动态饲喂的模式可以有效降低蛋鸡衰老所带来的负面影响,具有进一步研究的意义。

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Research Progress on Improving Eggshell Quality in Late Laying Period

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Abstract: Eggshell quality is an important indicator for evaluating egg quality. It is related to the breakage rate during the transportation and storage of eggs, and is directly related to the pass rate of breeding eggs, hatching rate and the health of chicks. It is one of the important factors affecting the production efficiency of laying hens. The aging of laying hens is the main factor leading to the decline of eggshell quality in the later stages of laying. Especially in recent years, the laying cycle of commercial laying hens has been greatly prolonged, and the aging degree of laying hens has been higher, resulting in a more serious problem of the decline of eggshell quality in the later stage of laying. This article summarized the reasons for the decline of eggshell quality in the late laying period from the eggshell formation process and calcium metabolism process, and summarized and prospected the solutions to improve the eggshell quality in the late laying period. [***Chinese Journal of Animal Nutrition*, 2021, 33(2):686-697**]

Key words: laying hens; late laying period; eggshell quality; uterine senescence; calcium metabolism

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