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定制鸡蛋生产的日粮营养调控

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摘 要

鸡蛋营养丰富，是优质的食用蛋白质来源。因普通鸡蛋胆固醇和饱和脂肪酸含量的原因，使鸡蛋成为一种有争议的食品。但是，通过对蛋鸡日粮采取一些营养调控措施，可以改变鸡蛋的营养成分。随着人们对健康的关注，希望从膳食中摄入有益于人体健康的功能性成分。定制鸡蛋即是近年来开发的能满足不同消费者特殊健康需求的鸡蛋，如低胆固醇鸡蛋、富ω-3 PUFA鸡蛋、富微量元素鸡蛋、富维生素鸡蛋、富类胡萝卜素鸡蛋等。文章综述了各种类型定制鸡蛋生产的日粮营养调控。

关键词

定制鸡蛋，营养调控，胆固醇，ω-3多不饱和脂肪酸，产蛋鸡

Dietary Nutritional Manipulation on Designer Eggs Production

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Abstract

Eggs are rich in nutrition and are a good source of edible protein. Due to the cholesterol and saturated fatty acid content of ordinary eggs, eggs have been controversial foods. However, the nutritional components of eggs can be altered through some nutritional manipulations of layer diets.

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With people's attention to health, it is hoped that functional ingredients beneficial to human health can be consumed from diets. Designed eggs are developed in recent years to meet the special health needs of different consumers, such as low cholesterol eggs, omega-3PUFA enriched eggs, mineral enriched eggs, vitamin enriched eggs, carotenoids enriched eggs and so on. This paper reviews the dietary nutritional manipulation on various types of designer eggs production.

Keywords

Designer Eggs, Nutritional Manipulation, Cholesterol, Omega-3 PUFA, Laying Hen

1. 引言

鸡蛋富含蛋白质、氨基酸、脂肪、各种矿物质和维生素(除维生素 C 外)，对人类来说是一种营养丰富的重要食品，也是最好和最便宜的优质蛋白质来源之一。因此，鸡蛋是全世界最受欢迎的食品之一。普通鸡蛋含胆固醇约 200~300 mg/100g、饱和脂肪酸约 3 g/100g (Li 等，2013) [1]。对保健机构和营养专家来说，鸡蛋是一种有争议的食品。他们认为对鸡蛋中胆固醇的摄入与潜在的心血管疾病存在关系，人们被提醒不要增加鸡蛋的摄入，导致人均鸡蛋消费量很低(Stadelman, 1999) [2]。但是，后来的研究证实，与饱和脂肪酸和总的脂肪酸比较，从鸡蛋中摄入的胆固醇对血中胆固醇水平和心血管紊乱的影响有限(Singh 等，2010 [3]；Eilat-Adar 等，2013 [4])。尽管如此，大家对鸡蛋的消费还是存在顾虑。实际上，通过蛋鸡日粮的营养调控，可以改变鸡蛋的营养成分(Laudadio 等，2011 [5])。定制鸡蛋(designer eggs)或功能性鸡蛋就是从人体健康的角度出发，根据不同消费者的需求，生产出富含一种或多种功能性成分的鸡蛋。目前，市场上已经出现了一些功能性鸡蛋，如低胆固醇鸡蛋、富 ω-3PUFA 鸡蛋、富微量元素鸡蛋、富维生素鸡蛋、富类胡萝卜素鸡蛋等(Alagawany 等，2018) [6]。定制鸡蛋是一种重要的功能性食品，可以改善人们饮食维生素、矿物质、平衡 ω-6 PUFA 和 ω-3 PUFA 的比例、必需色素如类胡萝卜素，降低总胆固醇和增强抗体水平。该文综述了定制鸡蛋生产的日粮营养调控，以期为鸡蛋消费和我国蛋鸡业的可持续发展提供科学依据。

2. 定制鸡蛋的调控

2.1. 低胆固醇鸡蛋

尽管人们对胆固醇是否对健康有不利影响仍存在争议，但是如果摄入胆固醇会增加血液中胆固醇的含量，那么消费者就很关注鸡蛋中胆固醇含量(Surai 等，2001) [7]。研究表明，通过蛋鸡日粮营养调控，有助于降低鸡蛋胆固醇。Ahmad 等(2012) [8]报道，在蛋鸡日粮中添加 ω-3 PUFA 可降低鸡蛋中胆固醇含量。杨蕊等(2014) [9]在蛋鸡日粮中添加 0.2%二十二碳六烯酸(DHA)或 0.3% α-亚麻酸(ALA)，显著降低了蛋黄中总胆固醇含量($P < 0.05$)。Lokhande 等(2014) [10]研究发现，在蛋鸡日粮中添加平卧菊三七(*Gynura procumbens*)可使蛋黄中胆固醇含量降低 12%。Laudadio 等(2014) [11]报道，蛋鸡日粮中使用苜蓿粉，血液和蛋黄中胆固醇的含量分别降低 13.7 和 19.1%。Shahid 等(2015) [12]、Skřivan 等(2019) [13]试验表明，蛋鸡日粮中应用大麻籽，可显著降低鸡蛋中的胆固醇($P < 0.05$)。上述植物原料降低鸡蛋胆固醇的机制是由于植物甾醇的存在可能降低了蛋鸡肠道中胆汁胆固醇的重吸收，进而抑制肝脏胆固醇合成。孟维珊等

(2017) [14]报道，在蛋鸡日粮中1%发酵中草药(山楂、草决明、益母草、泽泻、杜仲、绞股蓝、黄芪、松针、甘草等)，经4周试验，鸡蛋中胆固醇含量比空白对照组降低了37.89%。Wang 等(2015) [15]用22周龄蛋鸡试验发现，在日粮中添加1%、2%蛹虫草残基，鸡蛋胆固醇分别降低21.8%、22.5%。杨景晁(2016) [16]报道，在237日龄海兰灰蛋鸡日粮中添加0.2%地顶孢霉培养物，鸡蛋胆固醇降低了41.1%。Wen 等(2019) [17]研究表明，在蛋鸡日粮中添加1%~6%橡胶籽油，可降低蛋黄胆固醇含量。Hajra 等(2019) [18]报道，蛋鸡日粮中添加吡啶甲酸铬(1.0 ppm)、螺旋藻(0.02%)、鱼油(1.5%)和 *α*-生育酚(250 ppm)，蛋黄中胆固醇降低约20%。

2.2. 脂肪酸优化鸡蛋

ω-3 PUFA 包括二十碳五烯酸(EPA)、二十二碳五烯酸(DPA)、DHA 和亚麻酸(LNA)，*ω*-6 PUFA 包括花生四烯酸(ARA)和亚油酸(LA)。*ω*-3PUFA 是调节免疫功能的重要营养因子，对神经系统发育，降低血小板聚集、血栓形成、血压、动脉粥样硬化、抗肿瘤，抗炎性和心脏保护具有重要作用(Marshall 等，1994 [19]；Hamosh, 2008 [20])。研究表明，高的 n-PUFA 摄入量是体内 C18:3n-3 转化为 EPA 和 DHA 的主要限制因素。摄入平衡的 *ω*-6 PUFA/*ω*-3 PUFA 有利于心血管健康(Wijendran 等，2004 [21])。鸡蛋本身不富含 *ω*-3 PUFA，要生产富含 *ω*-3 PUFA 鸡蛋可以通过在蛋鸡日粮中添加一些特殊的原料来实现，如花生油、鱼油、红花油、亚麻子、鱼粉或海藻。人们通过食用定制鸡蛋而摄入的 *ω*-3PUFA 可以预防心血管疾病，如心脏病发作，并可以在饮食中取代鱼肉产品(Horrocks 等，1999) [22]。

Shahid 等(2015) [12]报道，在蛋鸡日粮中添加25%大麻籽，可显著降低蛋黄中肉豆蔻酸(C14:0)、软脂酸(C16:0)和硬脂酸(C18:0)的含量($P < 0.05$)，n-PUFA 及 *ω*-3 PUFA、*ω*-6 PUFA 显著增加($P < 0.05$)。Yalcin 等(2010) [23]在蛋鸡日粮中添加亚麻籽粕或鱼油，可以显著提高蛋黄中 *ω*-3PUFA 含量($P < 0.05$)。许多学者研究表明，蛋鸡日粮中用亚麻籽，显著提高蛋黄中 *ω*-3PUFA 含量(邓波等，2017 [24]；Kralik 等，2017 [25]；Omri 等，2019 [26]；Panaite 等，2019 [27]；Spasevski 等，2019 [28]；彭运智等，2020 [29]；Huang 等，2020 [30]，显著降低蛋黄中棕榈酸、硬脂酸含量(Omri 等，2019) [26]，降低蛋黄中 *ω*-6/*ω*-3 PUFA 比值(Neijat，2016 [31]；Jovo 等，2019 [32])。章平平等(2018) [33]试验发现，在蛋鸡日粮中分别添加15%亚麻籽、杜仲籽和紫苏籽，均显著增加蛋黄中 *ω*-3 PUFA 含量($P < 0.05$)。Mattioli 等(2016) [34]报道，蛋鸡日粮中添加发芽苜蓿或发芽亚麻籽，均显著提高蛋黄中 EPA、DHA、LNA 含量。

王浩等(2017) [35]报道，在26周龄京红蛋鸡日粮中添加胆碱1000 mg/kg 和0.5%裂殖壶菌油(*Schizochytrium* oil, SO)，经8周试验，结果表明，显著提高蛋黄中 *ω*-3 PUFA)和 DHA 含量($P < 0.05$)，显著降低 *ω*-6 PUFA 含量及 *ω*-6PUFA/*ω*-3 PUFA 值($P < 0.05$)。张亚男(2017) [36]在含2%裂殖壶菌粉蛋鸡日粮中添加胆碱和磷脂，可显著增加蛋黄 *ω*-3 PUFA 和 DHA 含量($P < 0.05$)。冯嘉(2018) [37]用藻油、亚麻籽油的研究，也得到了类似的结果。Wen 等(2019) [17]研究发现，蛋鸡日粮添加4%橡胶籽油可显著提高蛋黄 *ω*-3 PUFA 水平，*ω*-6/*ω*-3 PUFA 比值降低($P < 0.01$)。黄明旺(2019) [38]报道，在蛋鸡日粮中添加2%产油微生物高山被孢霉，显著提高鸡蛋中 ARA、DPA 与 DHA 含量($P < 0.05$)，*ω*-6/*ω*-3PUFAs 比值下降28.6% ($P < 0.05$)。Manor 等(2019) [39]研究发现，在蛋鸡日粮中添加11.5%和23%脱脂海洋微绿藻(*Nannochloropsis*)，极显著提高蛋黄中 EPA + DHA 的浓度 $P < 0.01$)。Moran 等(2019) [40]报道，在蛋鸡饲料中添加金黄色海藻(*Aurantiochytrium limacinum Microalgae*)能显著提高鸡蛋中 DHA 含量($P < 0.05$)。Kralik 等(2020) [41]在蛋鸡日粮中添加鱼油或裂壶藻(*Schizochytrium limacinum*)试验表明，二者均能极显著增加蛋黄中 *ω*-3 PUFA 的含量($P < 0.01$)，降低蛋黄 *ω*-6/*ω*-3 PUFA 的比值($P < 0.001$)。Feng 等(2020) [42]报道，在海兰褐蛋鸡日粮中添加微藻油或鱼油，显著增加蛋黄 DHA 和总 n-3PUFA 含量，降低 *ω*-6/*ω*-3 PUFA 的比值($P < 0.05$)。

Helzallah，2013 [43]研究表明，蛋鸡日粮中添加里氏乳杆菌(*Lactobacillus reuteri)*可以增加蛋黄脂肪酸中共轭亚油酸(CLA)含量。Kostogrys 等(2017) [44]用石榴籽油的研究也得到了类似的结果。另外，Goto 等(2019) [45]研究表明，用发酵饲料饲喂蛋鸡，可显著提高鸡蛋蛋白中亚油酸的富集。其机理可能是饲料经过发酵，提高了植物饲料中脂肪酸的转移率。

2.3. 富微量元素鸡蛋

硒是最重要的营养素之一，在人和动物营养中起到非常重要的作用(Tufarelli 和 Laudadio，2011) [46]。研究表明，硒有助于减少关节炎、癌症(Papp 等，2007) [47]、囊性纤维化、免疫缺陷、肌营养不良、糖尿病(Surai，2000a) [48]；降低与癌症相关的 DNA 损伤风险，改善血液流动性，为心血管疾病提供保护因子(Abdulah 等，2006) [49]，硒增强人体抗氧化功能(Venardos 等，2007) [50]，富硒鸡蛋可以降低骨质疏松性髋部骨折的风险(Zhang 等，2006) [51]。Surai (2000a; 2000b) [48] [52]报道，添加有机硒可以大大提高鸡蛋中硒的沉积。Gordana 等(2018) [53]报道，在蛋鸡日粮中添加 0.5 mg/kg 有机硒，鸡蛋蛋黄及蛋清中硒含量均极显著提高($P < 0.01$)。许多研究表明，在蛋鸡日粮中添加酵母硒(马丽娜等，2018 [54]；Lv 等，2019 [55]，Lu 等，2019 [56]，Moslehi 等，2019 [57])、硒代蛋氨酸[57]，均显著提高蛋黄中硒含量($P < 0.05$)。Hu 等(2020) [58]报道，在蛋鸡日粮中添加 0.5mg/kg 的酵母硒可获得富硒蛋($P < 0.05$)。Untea 等(2020) [59]报道，在蛋鸡日粮中添加 0.5%越橘(Bilberry)叶、1%核桃(walnut)叶，均显著提高蛋黄中锌含量($P < 0.05$)。Yu 等(2020) [60]报道，蛋鸡日粮中添加高剂量(70 mg/kg)无机锌或有机锌(Zn-Pro)均可显著提高鸡蛋中锌的含量。Esfahani 等(2020) [61]研究表明，蛋鸡日粮中添加低剂量(30 mg/kg)的有机锌(Zn-Met 或 Zn-Thr)即可达到富锌鸡蛋的效果。

2.4. 富维生素鸡蛋

杨景晁(2016) [16]在 237 日龄海兰灰蛋鸡日粮中添加 0.2%地顶孢霉培养物，蛋黄中维生素 A、D、E 含量均高于对照组，其中维生素 D、E 达到显著差异($P < 0.05$)。Browning 等(2014) [62]报道，蛋鸡日粮中添加高水平的 D_3 和 25-OH D_3，显著蛋黄中维生素 D 的含量($P < 0.05$)，可以满足成人和儿童的日常需求。Sarah 等(2017) [63]用 25-OH D_3 的研究也得到类似的结果。Gordana 等(2018) [53]报道，在蛋鸡日粮中添加 200 mg/kg 维生素 E，蛋黄中维生素 E 含量提高了 68.56% ($P < 0.01$)。Skřivan 等(2019) [13]在蛋鸡日粮中添加 6%大麻籽，蛋黄中 α-生育酚、γ-生育酚含量显著提高($P < 0.05$)。

2.5. 富类胡萝卜素鸡蛋

蛋黄中的一些类胡萝卜素不仅影响蛋黄的颜色，而且可以用于治疗或预防眼疾，如白内障、黄斑变性和抗衰老(Ribaya-Mercado 等，2004) [64]，增强人体抗氧化能力和减少脂类的过氧化危害(Cucco 等，2007) [65]。一些饲料原料如黄玉米、玉米酒精糟(DDGS)、玉米蛋白粉、苜蓿粉、万寿菊花粉和藻粉等类胡萝卜素含量较高。这些原料应用于蛋鸡日粮中，可以将饲料中的类胡萝卜素转移到蛋黄中(Laudadio 等，2014 [11])。Karadas 等(2006) [66]研究发现，在蛋鸡小麦/大麦型日粮中分别添加 2%苜蓿浓缩物、2%番茄粉、2%万寿菊提取物，均可显著提高蛋黄颜色评分和蛋黄中总类胡萝卜素含量。Hammershøj 等(2010) [67]报道，蛋鸡日粮中添加不同颜色(红色、橙色和紫色)的胡萝卜时，蛋黄红度和黄度显著增加。Shalash 等(2010) [68]和 Deniz 等(2013) [69]观察到，通过将蛋鸡日粮中的 DDGS 含量提高到 15%或 20%，蛋黄的颜色评分显著提高。Akdemir 等(2012) [70]报道，在蛋鸡日粮中添加不同的微藻(褐指藻、纳米绿藻和等鞭金藻)，可使蛋黄颜色由黄色变为红色。Panaite 等(2019) [27]在蛋鸡日粮中添加 5%亚麻籽和 7.5%番茄渣，饲喂 4 周后的结果表明，蛋黄中的叶黄素和玉米黄质含量分别提高了 29%和 24%。但是，类胡萝卜素向蛋黄的转移效率及其对蛋黄着色的影响，因类胡萝卜素的种类及其化学结构形式的不同而有很大差异。研究表

明，β-胡萝卜素对蛋黄着色没有影响，而叶黄素和玉米黄质是高活性的蛋黄着色剂(Loetscher 等，2013) [71]。Jang 等(2014) [72]报道，在蛋鸡日粮中添加商品叶黄素和菠菜粗提物可显著提高蛋黄蛋黄颜色和叶黄素的含量($P < 0.01$)。Manuela 等(2019) [73]在蛋鸡日粮中添加 2 g/kg 万寿菊提取物也得到了类似的结果。Panaite 等(2019) [27]报道，在蛋鸡日粮中添加 5%亚麻籽或 7.5%番茄渣，蛋黄中叶黄素和玉米黄质含量分别提高了 29%和 24%，颜色评分比对照组高 3.5 倍。Spasevski 等(2019) [28]在罗曼褐蛋鸡日粮中添加天然色素(1%胡萝卜和 0.5%辣椒粉)，获得了理想的蛋黄颜色(罗氏比色扇 12.78 分)。Untea 等(2020) [59]研究发现，在蛋鸡日粮中添加 0.5%越橘(Bilberry)叶或 1%核桃(walnut)叶，均可显著提高蛋黄中叶黄素和玉米黄质含量($P < 0.05$)。Gordana 等(2018) [53]给蛋鸡饲喂改良日粮(添加 5%混合油、0.5 mg/kg 有机硒、200 mg/kg 叶黄素、200 mg/kg 维生素 E)，结果显示，鸡蛋中叶黄素含量提高了 7.4 倍。Wen 等(2019) [17]研究表明，在蛋鸡日粮中添加橡胶籽油(1%、2%、4%、6%)，可显著改善蛋黄颜色($P < 0.05$)。

3. 结语

饮食是影响人体健康的最重要因素之一，这使人们努力开发具有高营养价值或特殊功能的食品，如可以调节人体免疫功能，降低血压，降低血液胆固醇，预防癌症、糖尿病和心血管疾病。鸡蛋可作为增加人体重要营养素摄入的有效载体。通过蛋鸡日粮调控，生产的定制鸡蛋含有对人体健康有益的多种营养成分和活性物质，如 ω-3PUFA、矿物质、维生素和类胡萝卜素等。随着人们对健康和功能性食品的日趋重视，定制鸡蛋具有广阔的市场前景。目前的研究主要集中在蛋鸡日粮原料的选择与营养素、功能性成分的富集效果，未来需要加强营养素、功能性成分在鸡蛋中代谢沉积规律的研究，为消费者生产更优化的定制鸡蛋产品。

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