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稻米淀粉、蛋白质和脂质与蒸煮食味品质关系研究进展

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摘要 蒸煮食味品质是消费者选择稻米的重要评价标准。淀粉、蛋白质和脂质作为稻米的三大主要物质成分,与其蒸煮食味品质关系密切。为进一步探索稻米蒸煮食味品质形成机制及水稻优质栽培技术,本文综述了稻米三大主要物质的组成与分布、合成代谢特点及其与蒸煮食味品质关系的研究进展,总结了干湿交替灌溉技术对稻米三大主要物质及其蒸煮食味品质的影响,并提出了研究存在三大主要物质互作与稻米蒸煮食味品质关系不清楚以及干湿交替灌溉对蒸煮食味品质的调控机制不明确等问题。建议今后基于淀粉、蛋白质和脂质累积与合成代谢的关系深入研究稻米蒸煮食味品质形成机制以及轻-干湿交替灌溉对稻米蒸煮食味品质的调优机制。

关键词 稻米;蒸煮食味品质;淀粉;蛋白质;脂质;干湿交替灌溉

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随着人们生活水平的日益提高,消费者对稻米品质提出了更高要求[1]。我国乃至全球市场对中高端大米的消费需求旺盛,尤其是对优质食味稻米的需求迫切[2]。稻米蒸煮食味品质作为最为关键的品质性状,其评价指标较为多样化。一般而言,稻米的食味品质以米饭的外观、黏度、硬度、适口性和气味等感官评价为衡量标准[3]。近年,米饭食味值也多用来作为稻米食味品质的评价标准[4-5]。稻米的蒸煮食味品质还可通过测定淀粉RVA谱特征值(如糊化温度、峰值黏度、热浆黏度、最终黏度、崩解值和消减值等)、直链淀粉含量以及胶稠度等理化指标进行定量分析[6-7]。

淀粉、蛋白质和脂质是稻米的三大主要物质成分,与稻米蒸煮食味品质形成密切相关[8]。阐明三大主要物质组分与蒸煮食味品质的关系对稻米食味的优质改良具有重要推动作用。干湿交替灌溉(alternating wet and dry irrigation, AWD)作为一项切实可行的节水灌溉技术,对水稻产量与品质形成具有重要调控作用[9]。明晰AWD技术对稻米三大主要物质及蒸煮食味品质的调控作用可为水稻高产节水优质栽培提供重要的理论与技术支撑。据此,本文对稻米淀粉、蛋白质和脂质的组成与分布、合成代谢特点及其与蒸煮食味品质关系的研究进展进行综述,并论述了AWD技术对稻米三大主要物质组分及蒸煮食味品质的调控作用。

1 稻米淀粉、蛋白质和脂质的组成与分布

水稻精米的物质组分包括淀粉、蛋白质、脂质、维生素以及矿物质等[10]。稻米中淀粉、蛋白质和脂质分别占85%～90%、7%～12%和0.3%～3.0%,是稻米的三大主要物质成分[10]。

1.1 淀粉的组成与分布

淀粉由直链淀粉(amylose)和支链淀粉(amylopectin)2种不同的聚合物构成[11]。直链淀粉是由*D*-葡萄糖以α-1, 4-糖苷键连接而成的没有分支的线性

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葡聚糖链，而支链淀粉是淀粉的主要组成成分，由多个较短的直链淀粉分支通过α-1，6-糖苷键链接于主链的多糖[12]。直链淀粉的分子结构使其较支链淀粉容易形成晶体结构，在烹饪过程中更容易形成稻米粒的外层“胶囊”[13-14]。支链淀粉结构的分支点使其能够形成更大的分子量，与直链淀粉相比具有更好的溶胀性和黏性[15]。水稻籽粒胚乳中的淀粉以半晶体状的淀粉粒形式存在，淀粉粒的形态大小与粒度分布会因品种和环境的影响而不同[16-17]。

1.2 蛋白质的组成与分布

稻米的蛋白质含量和成分因品种、产地、生长发育条件以及加工精度等因素而异[18]。稻米中的贮藏蛋白根据其溶解性不同可分为4种组分：①谷蛋白(溶于稀碱或稀酸)；②醇溶蛋白(溶于乙醇)；③清蛋白(溶于水)；④球蛋白(溶于盐溶液)[19]。其中，稻米蛋白质的主要部分是分布在胚乳中的谷蛋白和醇溶蛋白，其次是分布在稻米糊粉层中的清蛋白和球蛋白[20]。谷蛋白和醇溶蛋白的含量与比例被认为是影响稻米蛋白质品质的重要因素[21]。此外，我们都知道蛋白质的基本结构单元或合成底物是各类氨基酸，蛋白质的生物合成包括氨基酸的活化、蛋白质合成的起始、肽链的延伸和肽链的终止等一系列过程[12]。因此，各种氨基酸的生物合成过程实质上就是蛋白质合成代谢的主要组成部分。

1.3 脂质的组成与分布

脂质，又称为脂类，在稻米中分布不均匀，一半分布在米胚部位，30%左右分布在表层，20%左右在胚乳层[22]。据报道，糙米和精米中脂类的含量一般分别为1%～4%和0.2%～2.0%[23]。通常，稻米脂类被分为淀粉脂类和非淀粉脂类[24]。淀粉脂类主要存在于稻米胚乳淀粉颗粒中，如脂肪、磷脂和糖脂；非淀粉脂类主要存在于稻米的皮层(种皮和糊粉层)，如脂肪酸、溶血卵磷脂[24]。其中，脂肪即三酰甘油或称甘油三酯，由甘油和脂肪酸组成，是稻米中最为丰富的一类单纯脂质[12]。脂肪酸主要有油酸(C18:1)、亚油酸(C18:2)和棕榈酸(C16:0)，这3种游离脂肪酸约占稻米脂肪酸总量的90%；其他脂肪酸有硬脂酸(C18:0)、亚麻酸(C18:3)和花生酸(C20:0)等[25-26]。其中，油酸、亚油酸和亚麻酸是人体生长发育需要的3种必需脂肪酸[12]。

2 水稻籽粒中淀粉、氨基酸和脂肪的合成代谢

2.1 淀粉的合成代谢

水稻的籽粒灌浆实质上就是淀粉的生物合成与积累过程。水稻叶片产生的光合同化物以蔗糖形式卸载进入籽粒中，随后在胚乳细胞的淀粉体中经过一系列的酶促反应生成淀粉(图1)[12]。这些酶促反应中，蔗糖合酶(sucrose synthase，SuSase)、腺苷二磷酸葡萄糖焦磷酸化酶(adenosine diphosphoglucose pyrophosphorylase，AGPase)、颗粒结合性淀粉合酶(granule-bound starch synthase，GBSS)、可溶性淀粉合酶(soluble starch synthase，SSS)、淀粉分支酶(starch branching enzyme，SBE)和淀粉去分支酶(starch debranching enzyme，DBE)等对稻米淀粉的合成起着关键作用[27-28]。GBSS、SSS和SBE对直链淀粉和支链淀粉的生物合成都发挥作用[29]。而且，负责直链淀粉合成的GBSS活性与负责支链淀粉合成的SSS活性具有相关性[29]。据报道，水稻花后轻干-湿交替灌溉处理可增强弱势粒中淀粉合成相关酶活性及其基因表达，进而促进弱势粒中淀粉的合成与积累[30]。Zhang等[31]观察到，籽粒灌浆速率与细胞分裂素(玉米素和玉米素核苷)、吲哚-3-乙酸、多胺(亚精胺和精胺)以及脱落酸含量呈显著正相关，外源喷施上述生长调节剂有望增加籽粒灌浆速率和粒重。

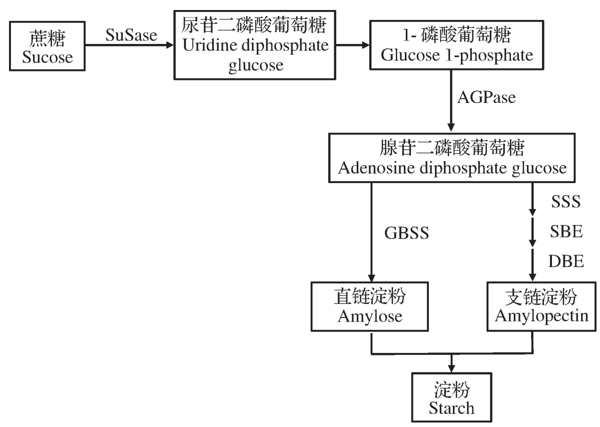

图1 淀粉合成主要途径

Fig.1 Main pathways of starch synthesis

2.2 氨基酸的合成代谢

高等植物在氮代谢过程中，其叶片、叶鞘和茎秆等器官中的无机氮(NH_4^+)只有转换成有机氮(如：氨基酸和酰胺)的形式输送到籽粒中才能合成蛋白质，而且95%以上的无机氮则是通过谷氨酰胺合成酶/谷氨酸合成酶循环途径被同化[32]。各类氨基酸

的生物合成是由谷氨酰胺合成酶(glutamine synthetase, GS)、谷氨酸合成酶(glutamate synthetase, GOGAT)、天冬氨酸转氨酶(aspartate transaminase, AST)、天冬氨酸激酶(aspartate kinase, AK)和丙氨酸转氨酶(alanine transaminase, ALT)等一系列酶催化进行[12,33],如图2所示。近年,大量研究表明较高的多胺(亚精胺和精胺)和油菜素甾醇(24-表油菜素内酯和28-高油菜素内酯)在水稻籽粒氨基酸的生物合成中发挥积极作用,主要是通过增强籽粒中上述氨基酸生物合成相关酶活性[34-35]。相反地,乙烯可能通过抑制参与氨基酸生物合成的酶活性和提高活性氧含量来阻碍氨基酸的生物合成[36]。

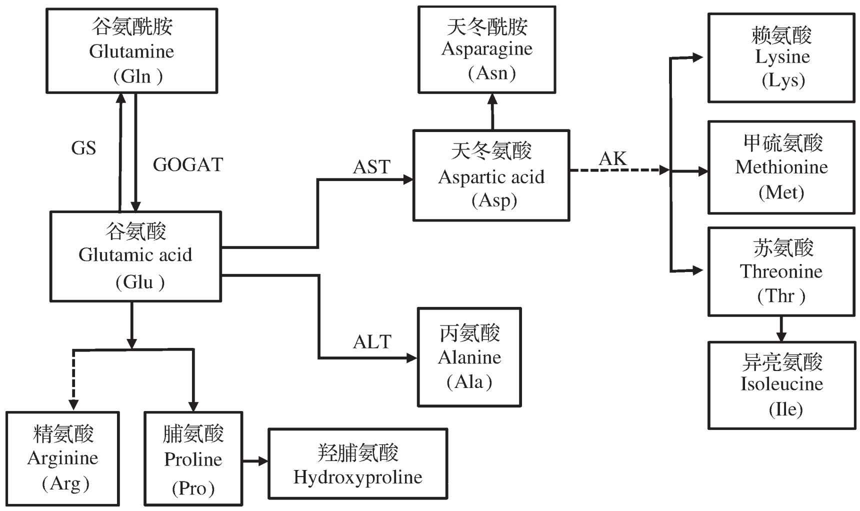

图2　主要氨基酸合成代谢途径

Fig. 2　Anabolic pathways of main amino acids

2.3　脂肪的合成代谢

脂肪的合成代谢途径也较为复杂,体现在脂肪酸的生物合成和磷酸甘油的生物合成,主要途径见图3[12,37]。在水稻籽粒的发育过程中,籽粒细胞中的葡萄糖在糖酵解途径中会产生大量的脂肪合成前体(如丙酮酸、磷酸二羟丙酮),一方面丙酮酸经过氧化脱羧形成乙酰辅酶A,另一方面磷酸二羟丙酮会生成3-磷酸甘油[12]。在整个合成过程中,乙酰辅酶A羧化酶(acetyl-CoA carboxylase, ACCase)、脂肪酸合酶(fatty acid synthase, FAS)、硬脂酸脱氢酶(stearate dehydrogenase, SAD)、脂肪酸脱氢酶(fatty acid dehydrogenase, FAD)、3-磷酸甘油脱氢酶(glycerol 3-phosphate dehydrogenase, G3PD)、磷脂酸磷酸酯酶(phosphatidate phosphatase, PPase)和二酰甘油酰基转移酶(diacylglycerol acyltransferase, DGAT)都是脂肪合成的关键酶[12,37]。据报道,增施磷钾肥可通过提高籽粒中脂质合成相关酶活性进而优化稻米中脂肪酸组分以及增加脂质含量[38-39]。此外,外源施用赤霉素(GA_3)可通过增强脂质合成关键酶(单半乳糖甘油二酯合酶)的表达来提高盐胁迫下水稻叶绿体膜脂质的生物合成[40]。

2.4　糖类、氨基酸和脂质合成代谢的关系

水稻籽粒中的淀粉、氨基酸和脂质合成代谢并不是彼此孤立存在的,而是同时进行、相互依存的[41-42]。据报道,虽然三大主要物质成分的代谢途径各有不同,但是它们能够通过共有的中间产物(乙酰CoA)和三羧酸循环(tricarboxylic acid cycle, TCA)途径联系在一起[41]。而且,3种酮酸(丙酮酸、草酰乙酸和α-酮戊二酸)在糖类、氨基酸和脂质的合成代谢过程中发挥着中枢纽带的重要作用[42]。具体地说,糖类在有氧代谢过程中形成的丙酮酸,能进一步氧化脱羧变成乙酰辅酶A进入TCA循环;乙酰辅酶A又是脂肪酸合成的原料;与此同时,上述3种酮酸可作为碳骨架的来源,合成各种不同的氨基酸(图4)。

3　稻米淀粉、蛋白质和脂质与蒸煮食味品质的关系

3.1　稻米淀粉与蒸煮食味品质的关系

国际上,通常以直链淀粉含量作为稻米蒸煮食味品质的重要评价指标[43]。直链淀粉含量高的水稻籽粒硬度大、黏度低,而支链淀粉含量越高的籽粒黏度越大[44]。而且,直链淀粉与稻米食味品质的相关性会因稻米中直链淀粉含量的不同而有差异[45]。Zhang等[46]曾以9个淀粉组分不同的水稻突变体为材料研究淀粉特性与品质的关系,发现淀粉含量及

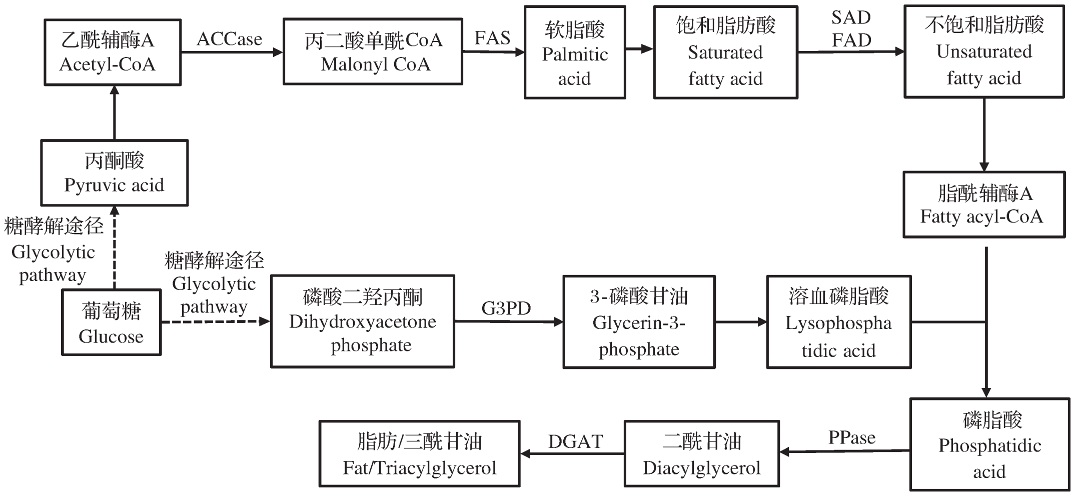

图3 脂肪合成主要途径

Fig. 3 Main pathways of fat synthesis

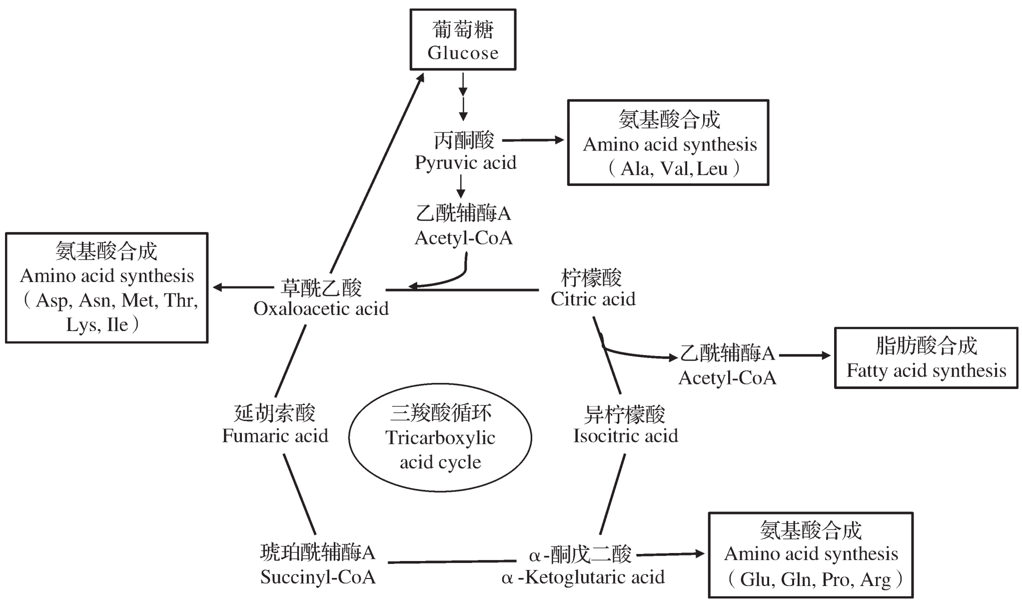

图4 乙酰辅酶A、丙酮酸、草酰乙酸和α-酮戊二酸在糖类、氨基酸和脂质合成过程中发挥的作用

Fig. 4 Roles of acetyl-CoA，pyruvic acid，oxaloacetic acid and α-ketoglutaric acid in the synthesis of sugars，amino acids and lipids

其组分比例的变化会引起淀粉糊化特性的改变。Tao等[43]进一步提出，高直链淀粉水稻品种的食味品质差不仅与直/支链淀粉比例高有关，还与淀粉的精细分子结构有关(即支链淀粉分支更长)。后来，Peng等[47]利用直链淀粉含量相同而食味值不同的杂交稻为材料进行研究，发现支链淀粉短链比例增加、长链比例减少的稻米崩解值和峰值黏度升高，米饭口感软黏。可以说，稻米的淀粉含量、结构组成及其比例是影响稻米蒸煮食味品质的重要因子。

3.2 稻米蛋白质与蒸煮食味品质的关系

稻米蛋白质是影响其蒸煮食味品质的重要因素之一。关于蛋白质与稻米蒸煮食味品质的关系，目前报道不一、存在分歧。大部分学者认为，蛋白质含量与稻米胶稠度[48]、淀粉崩解值和峰值黏度[48-49]以及米饭食味值[50]呈极显著负相关，与消减值[48-49]呈极显著正相关，增加稻米蛋白质含量对其蒸煮食味品质具有负面影响。究其原因，可能是蛋白质含量高的稻米内部排列结构致密、胚乳中淀粉粒空隙小，进而影响淀粉在蒸煮过程中的糊化作用，导致了淀粉糊化温度的升高、米饭熟度的降低[51-52]。王有伟等[53]也提出，优质食味稻米的蛋白质含量相对较低。然而，也有少数研究者[54]提出一定范围内的蛋白增

加对稻米食味无显著影响。而且，半糯型优良食味稻米中蛋白质含量也较高[55]，这表明优质食味稻米中的蛋白质含量不一定低。石吕等[48]在进一步分析了稻米4种蛋白组分与其蒸煮食味品质相关性后指出，稻米清蛋白含量与食味值的关系因品种而异，谷蛋白、醇溶蛋白和球蛋白含量与食味值呈显著负相关。芮闯等[56]也观察到，谷蛋白含量与米饭食味品质和适口性均呈显著负相关。而且，有Yang等[57]发现利用CRISPR/Cas9基因编辑技术敲除编码籽粒谷蛋白的相关基因能够显著改善稻米的蒸煮食味品质。但是，也有关于稻米中醇溶蛋白增加可提高米饭口感的相关报道[58]。综上，我们认为蛋白质含量及其组分对稻米蒸煮食味品质的影响及机制亟待深入研究。

3.3　稻米脂质与蒸煮食味品质的关系

相对于淀粉和蛋白质，稻米脂质含量比较低，但其与稻米蒸煮食味品质的关系也相当密切[8]。研究表明，稻米脂质中的糖脂和磷脂与直链淀粉组成的复合物能阻碍淀粉膨胀、增加糊化温度，从而改变了稻米的蒸煮食味品质[59]。据报道，粳稻脂肪含量与食味值和崩解值呈显著正相关，与直链淀粉含量呈极显著负相关[60]。而且，脂肪含量的增加会促使米粉黏度下降，比如脱脂米粉的热浆黏度、冷胶黏度和峰值黏度都明显高于未脱脂米粉[61]。吴焱等[62]观察到，相比于低脂和高脂类型水稻品种，中脂类型品种的未脱脂米粉具有较高的糊化热焓值、较低的回生热焓值和回生度以及较好的食味品质和质构特性。还有研究表明，食味值与稻米脂肪酸含量呈显著负相关，而且脂肪酸含量受土壤水分的影响程度较大[63]。但是，毕雪等[64]指出，在一定范围内，随着油酸和亚油酸添加量的增加，其与稻米淀粉形成的淀粉-脂质复合物便会增多，进而增加米饭硬度，降低米饭黏度，与此同时会显著提高稻米米粉的最终黏度和回升值。也有研究显示，脂肪酸脱氢酶基因*FAD2-1*的表达下调能显著改变水稻籽粒胚乳中溶血磷脂的组分含量，进而影响淀粉特性[65]。此外，水稻籽粒中1种磷脂酶D基因*OsPLDa1*的突变会增加溶血磷脂的含量，进而提高稻米的蒸煮与食味品质[66]。近年，Xia等[67]在水稻上克隆了1个QTL（*qFC6*，基因号为*LOC_Os06g04200*），*qFC6*是控制稻米粗脂肪含量和蒸煮食味品质的1个主效基因，可以正向调控稻米中结合脂质的含量，而负面影响游离脂质含量以及米饭的口感[67]。

3.4　稻米淀粉、蛋白质和脂质互作与蒸煮食味品质的关系

关于稻米淀粉、蛋白质和脂质互作与蒸煮食味品质关系的报道中，淀粉和蛋白质与蒸煮食味品质的关系研究相对较多。研究表明，稻米中直链淀粉含量、蛋白质含量与食味品质之间的关系会受到直链淀粉和蛋白质含量变异幅度的影响，并指出低直链淀粉、低蛋白的水稻品种应为食味优良品种[45]。稻米中蛋白质松弛或紧密地结合到淀粉颗粒，一方面通过二硫键等特殊结构与淀粉作用形成网络结构抑制淀粉分子链间的相互作用，抑制淀粉的进一步膨胀，另一方面作为催化淀粉生物合成的酶，影响淀粉特性和米饭质构[68]。张向民等[69]指出，稻米中直链淀粉会与游离脂肪酸或磷脂形成淀粉脂复合物，影响米饭黏弹性，而脱脂后淀粉糊化温度和凝胶黏度都会有所降低。此外，有学者发现稻米蛋白质在蒸煮过程中会与直链淀粉-脂质复合物结合，促进v型衍射峰的形成[70]。而且，高施氮量处理会使稻米蛋白质具有更多的β-片层结构，从而减缓水分进入淀粉分子内部，防止淀粉的短程有序结构被破坏[70]。上述说明，淀粉、蛋白质和脂质能够相互作用，共同影响着稻米的蒸煮食味品质。

4　干湿交替灌溉对稻米淀粉、蛋白质、脂质及蒸煮食味品质的影响

4.1　干湿交替灌溉技术

干湿交替灌溉（AWD）技术以在水稻生长发育进程中保有土壤水层与自然落干的循环往复为特征[9]。关于AWD对水稻产量与品质形成的调控研究一直备受关注，其模式主要有2种类型[71-72]：①轻-干湿交替灌溉（alternating wet and moderately dry irrigation, AWMD），自土壤保有2～3 cm浅水层后落干至水势达（−15±5）kPa（15～20 cm深）时再复水，如此交替循环；②重-干湿交替灌溉（alternating wet and severely dry irrigation, AWSD），自土壤保有2～3 cm浅水层后落干至水势达（−35±5）kPa时再复水，如此交替循环。

4.2　干湿交替灌溉对稻米淀粉特性的影响

AWD技术对稻米淀粉特性的调控效应因土壤落干程度的不同存在差异。研究表明，AWMD技术较常规灌溉（CI）降低了稻米直链淀粉含量[73]、增加

了支链淀粉和总淀粉含量[74]。研究还显示，在AWMD条件下，稻米胚乳淀粉体排列更为紧密，而在AWSD下稻米胚乳淀粉体排列疏松、体积减小[75]。近年，张耗等[74]进一步观察到，AWMD技术还提高了1.5～20 μm淀粉粒的数量与体积比例，减少了＞20 μm淀粉粒的数量与体积比例以及淀粉的相对结晶度。Xiong等[75]也观察到，AWMD减少了精米中粒径＞10 μm淀粉粒的大小以及支链淀粉的短链分布比例，提高了支链淀粉的中、长链分布比例。此外，与CI相比，AWMD可显著提高淀粉的最终黏度、热浆黏度和消减值，而AWSD方式的效应相反[76]。这些研究表明，AWMD对稻米淀粉特性具有调优效应。

4.3 干湿交替灌溉对稻米蛋白质特性的影响

AWD技术对稻米蛋白质特性的研究相对较少。Chen等[77]曾发现，AWMD技术可上调水稻弱势粒中甘油醛-3-磷酸脱氢酶、丙酮酸磷酸双激酶、S-腺苷甲硫氨酸合酶、乙二醛酶Ⅰ、5-甲基四氢叶酸-同型高半胱氨酸甲基转移酶以及锰超氧化物歧化酶等的表达，而AWSD处理下调了弱势粒中这些酶的表达。水稻籽粒中，上述6种关键酶为参与光合作用、糖代谢、能量代谢、蛋白质和氨基酸代谢等的相关蛋白质[77]。另外，AWSD还增强了抑制能量代谢和信号转导相关蛋白的表达水平[77]。这些说明AWD技术必然会对稻米蛋白质特性产生重要影响。Xu等[76]观察到，AWMD处理降低了精米中醇溶蛋白的含量，进而降低了总蛋白含量，对其他蛋白组分含量无显著影响。张耗等[74]却发现，与常规灌溉相比，AWMD对精米4种蛋白组分的含量都无显著影响，但呈现出了提高清蛋白和谷蛋白含量、降低醇溶蛋白含量的变化趋势，可以调优蛋白组分。关于AWD对稻米蛋白质及其组分含量的差异影响可能是因供试品种、生长环境和落干程度的不同而异。

4.4 干湿交替灌溉对稻米脂质特性的影响

关于AWD技术对稻米脂质特性的影响研究较为少见。近来，笔者所在课题组以扬稻6号(YD6)和南粳9108(NJ9108)为供试材料，发现全生育期AWMD处理较常规灌溉(CI)显著增加了2个供试水稻品种精米中脂肪含量，而AWSD则降低了脂肪含量(图5)。同时，我们还通过非靶向脂质组学技术分析了扬稻6号精米中全部脂类物质对AWD技术的响应特点。结果显示，与CI相比，AWMD和AWSD模式下均有大量的脂质分子的表达明显上调或下调(表1)。这些研究结果表明，AWD技术对稻米脂质特性具有重要的调控作用，需要深入探究。

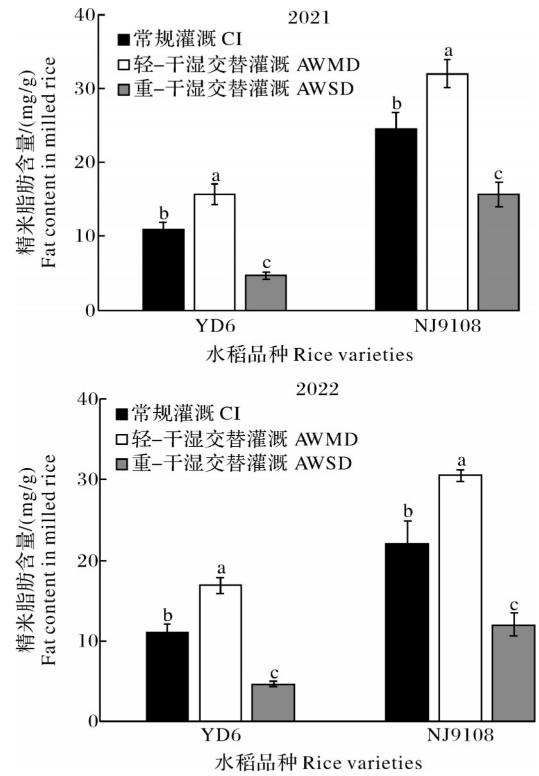

图5 不同干湿交替灌溉对2个水稻品种精米中脂肪含量的影响(笔者所在课题组，待发表)

Fig. 5 Effects of different alternating wet and dry irrigation regimes on fat content in milled rice of two rice varieties(Results of the author's research group to be published)

表1 不同干湿交替灌溉条件下扬稻6号(YD6)精米中脂质分子的差异表达数

Table 1 Number of differential expressions of lipid molecules in milled rice of Yangdao 6 (YD6) under different alternating wet and dry irrigation regimes

组别 Comparison groups	上调差异数 The number of up-regulated lipid molecules	下调差异数 The number of down-regulated lipid molecules	差异总数 Total number of differential lipid molecules
AWMD vs CI	296	87	383
AWSD vs CI	211	258	469
AWMD vs AWSD	354	154	508

注：数据为笔者所在课题组待发表研究结果。Note：The data were results of the author's research group to be published.

4.5 干湿交替灌溉对稻米蒸煮食味品质的影响

研究表明，AWMD可显著提高稻米的蒸煮食味品质(米粉的峰值黏度和崩解值提高、最终黏度和消减值降低)，而AWSD处理会显著降低稻米的蒸煮食

味品质[76]。周婵婵等[78]发现,2个东北粳稻的蒸煮食味品质在不同施氮水平下均以AWMD方式为佳。而且,高氮水平下AWSD处理的蒸煮食味品质优于浅水层灌溉[78]。这些结果说明,AWMD方式对稻米蒸煮食味品质具有重要调优作用,而AWSD方式也具有缓和高氮对稻米蒸煮食味品质带来负面影响的趋势。

5 问题与展望

淀粉、蛋白质和脂质的结构与生化特性共同决定着稻米的蒸煮食味品质。但是,前人多侧重于单个稻米成分与其蒸煮食味品质关系的研究,关于三大主要物质成分的含量比例、合成代谢关系及组成结构对稻米蒸煮食味品质的影响研究较为少见。因此,建议今后开展以下相关研究:①水稻灌浆进程中籽粒淀粉、蛋白质和脂质的含量变化特性及相互关系与蒸煮食味品质的关系;②水稻灌浆进程中籽粒淀粉、蛋白质和脂质的合成代谢特点及其互作机制与蒸煮食味品质的关系;③稻米淀粉、蛋白质和脂质的组成结构及相互关系与蒸煮食味品质的关系。

以往研究局限在基于水稻灌浆期籽粒淀粉合成代谢特点解析不同AWD方式对稻米品质形成的调控机制,对籽粒的其他两大重要物质成分(蛋白质和脂质)累积特征及其合成代谢变化特点缺乏全面而深入的探究。在不同AWD条件下,水稻灌浆进程中籽粒淀粉、蛋白质和脂质三大物质成分的含量动态变化及其组成比例与稻米蒸煮食味品质形成具有何种关系?水稻灌浆籽粒中淀粉、蛋白质和脂肪合成代谢关键酶活性及其相关编码基因表达的变化特点对不同AWD方式的响应机制是什么?在主要依赖增施氮肥来稳产增产的大背景下,AWMD对氮肥增施条件下的稻米蒸煮食味品质是否具有调优作用?作用机制是什么?目前都尚不清楚。通过对上述问题的探究,可望进一步揭示AWD技术对稻米蒸煮食味品质形成的调控机制,开发改善稻米品质的新途径,为稻米优质改良和高产节水优质栽培提供理论依据和技术支撑。

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Progress on relationship between starch, protein, lipids and taste quality of steaming and cooking in rice

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Abstract The taste quality of steaming and cooking is an important evaluation criterion for consumers when choosing rice. Starch, protein, and lipids, as the three main components of rice, are closely related to the taste quality of steaming and cooking in rice. This article reviewed the progress on the composition and distribution, anabolic characteristics of the three main components in rice and their relationship with the taste quality of steaming and cooking to further study the formation mechanism of the taste quality of steaming and cooking in rice and the techniques for cultivating the rice with high quality. The effects of irrigation with alternating wet and dry (AWD) on the three main components of rice and the taste quality of steaming and cooking in rice were summarized. Problems including the unclear relationship between the interaction of the three main components of rice and the taste quality of steaming and cooking in rice and the unknown mechanisms underlying the effects of AWD on the taste quality of steaming and cooking in rice were pointed out. It is recommended to conduct in-depth studies on the formation mechanism of the taste quality of steaming and cooking in rice and the regulatory mechanism of AWD on the taste quality of steaming and cooking in rice based on the relationship between the accumulation of starch, protein, and lipids and the anabolism of starch, protein, and lipids in the future.

Keywords rice; the taste quality of steaming and cooking; starch; protein; lipids; irrigation with alternating wet and dry

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