黄精——一种潜力巨大且不占农田的新兴优质杂粮

斯金平^{1*}, 朱玉贤²

1. 浙江农林大学, 省部共建亚热带森林培育国家重点实验室, 杭州 311300;

2. 武汉大学高等研究院, 武汉 430072

* 联系人, E-mail: lssjp@163.com

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摘要 黄精(*Polygonati rhizoma*)始载于我国第一部药学专著《神农本草经》,“以其得坤土之精粹”而得名,是传统经典的食药两用植物,可以代替粮食. 现代研究表明,黄精根茎不含淀粉,富含非淀粉多糖、低聚果糖、甾体、三萜皂苷、黄酮等营养和功效成分,具有补气养阴、健脾、润肺、益肾之效,特别是非淀粉多糖、低聚果糖,与抗性淀粉同样具有降低餐后血糖的作用,而且可以通过促进胰岛素分泌和提高胰岛素敏感性调节血糖、提高免疫力,是糖尿病患者、老年人性价比最高的食疗产品之一. 黄精多年生,无需每年播种,生长季节长,具有广泛的抗逆性,可做到一次种植永续采收,符合建立多样化的多年生粮食种植体系的现代理念,是实现农业可持续发展的重要手段;天然多倍化和非整倍化现象,为倍性育种提供了天然材料;适合亚热带、温带、寒温带林下大规模种植,不需良田、不占耕地、不争林地、不要仓储,“藏粮于林下”,是保障国家粮食安全、粮食产业转型升级的新路径;利用现有技术,林下规范种植每公顷产1500 kg干品,按现行市场价75元/kg计算,每公顷年产值112500元,从而实现山区群众不砍树也能富,真正实现“绿水青山就是金山银山”. 如果10%的储备林、5%经济林下种植黄精,可生产黄精569万吨,种植业产值可达4268亿元. 黄精遗传多样性丰富,品种改良与高效栽培潜力巨大,深入挖掘黄精根茎淀粉缺失机制,可为其他粮食作物品质改良提供重要理论基础.

关键词 黄精, 粮食, 淀粉, 药食同源, 林下种植, 多年生, 多倍化, 非淀粉多糖

民以食为天,食以安为先. 粮食安全一直是人类追求和奋斗的目标^[1]. 在过去半个世纪中,粮食供应虽然显著增加,但2019年全球仍然有近6.9亿人遭受饥饿,与2018年相比增加1000万,与5年前相比增加近6000万;2020年由于新冠肺炎疫情引发的全球经济衰退,饥饿人数至少新增约8300万(《世界粮食安全和营养

状况》2020年度报告). 联合国秘书处经济和社会事务部(United Nations Department of Economic and Social Affairs, UNDESA)《2019年世界人口展望: 重点》的报告指出,尽管世界人口增长速度放缓,但预计仍将从目前的77亿增加到2030年的85亿、2050年的97亿,到21世纪末可能达到近110亿的峰值,人口的增加对未

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来粮食安全提出新的挑战。其次, 水稻、玉米和小麦三种作物提供了世界60%的粮食摄入量, 超过20亿人口患有“隐性饥饿”, 联合国粮食及农业组织(Food and Agriculture Organization of the United Nations, FAO) 2018年报道, 亚太区域有4.79亿营养不良人口, 7720万5岁以下儿童发育迟缓, 3250万儿童身体瘦弱^[2]; 国际糖尿病联盟(International Diabetes Federation, IDF) 2019年《全球糖尿病概览》(第9版)显示, 全球共有4.63亿糖尿病患者, 中国患者人数排名第一, 约1.164亿人。因此, 粮食生产从满足“吃得饱”向“吃得营养健康”转变成为新的热点, FAO正在利用农业生物多样性来确定既多产又有营养的新一代作物, 山药、荞麦、南瓜等作物已经受到国际社会高度重视^[2], 而黄精更具有其特色和优势。

黄精“以其得坤土之精粹”而得名, 始载于我国第一部药学专著《神农本草经》(25~220年), 是传统经典的食药两用植物, 可以代替粮食^[3]。现代研究表明, 黄精属植物在全球范围内有60多种, 中国自然分布约39种(《中国植物志》*Flora of China*英文修订版, <http://www.iplant.cn/foc>), 多数具有重要的食用和药用价值^[4,5]。2020年版《中国药典》“黄精”包含了黄精(*Polygonatum sibiricum*)、滇黄精(*P. kingianum*)、多花黄精(*P. cyrtoneura*)3个基源物种, 具有补气养阴、健脾、润肺、益肾等功效^[6]。黄精根茎具有不含淀粉, 富含非淀粉多糖、低聚果糖, 多年生、倍性变异大、喜阴, 适合亚热带、温带、寒温带林下大规模种植等重要特性, 可望成为一种潜力巨大且不占农田的新兴优质杂粮。

1 黄精食药同源, 自古可以替代粮食

黄精口感好, 可长期大量食用, 自古可以代粮^[3]。《名医别录》(220~450年)等历代本草著作均记载, 黄精久服轻身、延年、不饥。《抱朴子内篇》(317年)记载: “服黄精仅十年, 乃可大得其益耳。”“黄精甘美易食, 凶年可以与老小休粮, 人不能别之, 谓为米脯也”。《食疗本草》(713~741年)首次记载“九蒸九曝”“饵黄精, 能老不饥。”“其生者, 若初服, 只可一寸半, 渐渐增之。十日不食, 能长服之, 止三尺五寸。”“根、叶、花、实, 皆可食之”。其后《本草纲目》(1552年)集历代本草记载, “黄精为服食要药, 故《别录》列于草部之首, 仙家以

为芝草之类, 以其得坤土之精粹, 故谓之黄精。”“嘉谟曰: 根如嫩姜, 俗名野生姜。九蒸九曝, 可以代粮, 又名米脯。”2002年, 黄精被列入卫生部(国务院原有组成部门)公布的86种《既是食品又是药品的物品名单》(卫法监发〔2002〕51号)。

现代研究表明, 黄精含有丰富的营养物质和功效成分。黄精根茎多糖、低聚果糖和果糖等含量约占50%, 蛋白质11.16%以上, 含有7种人体所需的必需氨基酸, 味觉氨基酸丰富, 口感佳^[6~8]。根茎中还有丰富的甾体、三萜皂苷、黄酮、生物碱类、木脂素类、挥发油类等功效成分, 其中以母核为薯蓣皂苷元和亚莫皂苷元的甾体皂苷为主的皂苷类化合物达110余种, 总含量3.16%~5.05%; 高异黄酮类、二氢黄酮类、查尔酮类、异黄酮类、紫檀烷类等黄酮类化合物, 总含量0.66%~1.91%^[9~13]。具有补气养阴、健脾、润肺、益肾之效, 用于脾胃气虚、体倦乏力、胃阴不足、口干食少、肺虚燥咳、劳嗽咳血、精血不足、腰膝酸软、须发早白、内热消渴等病症^[6]。

2 黄精根茎不含淀粉, 富含非淀粉多糖

世界主要粮食作物主要成分均由淀粉组成, 如稻米(~80%)、小麦(60%~70%)、小米(59.4%~70.2%)、马铃薯(70%~85%)^[14~17]。近年来, 因高蛋白、低淀粉而闻名的藜麦淀粉含量也在58.1%~64.2%^[18~20]。为了降低餐后血糖和胰岛素应答, 有效控制糖尿病病情, 抗性淀粉育种成为当前品质改良热点, 但育成的粮食作物中抗性淀粉所占比例仍然较低^[21,22]。

碘染法和细胞学观察发现, 黄精根茎中不含淀粉(图1A~C), 非淀粉多糖、低聚果糖和果糖是其养分主要贮存形式。非淀粉多糖和低聚果糖是世界公认的优质膳食纤维, 在人体小肠内不被消化和吸收, 对于调节血糖水平效果明显, 其在大肠内主要形成短链脂肪酸, 促进结肠健康细胞形成, 降低结肠直肠癌风险, 改善肠道菌群、增加矿物质吸收, 增强对有害病原体的免疫力^[23~28]。果糖甜度是蔗糖的1.2~1.5倍, 可在人体内代谢产生能量, 血糖指数(glucose index, GI)仅为葡萄糖的1/5, 适量服用可显著降低餐后血糖^[29,30]。非淀粉多糖和低聚果糖不仅具有抗性淀粉降低餐后血糖的作用, 而且可以通过促进胰岛素分泌和提高胰岛素敏感性调节血糖^[31,32]。此外, 黄精多糖还有抗衰老、降

图 1 多花黄精种子和根茎碘染实验和细胞学观察. A: 黄精根茎组织; B: 黄精根茎碘染; C: 黄精根茎半薄切片PAS染色; D: 黄精种子; E: 黄精种子碘染; F: 黄精种子半薄切片PAS染色

Figure 1 Iodine staining and cytological observation of *P. cyrtonema* seed and rhizome. A: *P. cyrtonema* rhizome tissue; B: iodine staining of *P. cyrtonema* rhizome tissue; C: periodic acid-Schiff (PAS) staining of *P. cyrtonema* rhizome semi-thin section; D: *P. cyrtonema* seed tissue; E: iodine staining of *P. cyrtonema* seed; F: PAS staining of *P. cyrtonema* seed semi-thin section

血脂、防动脉粥样硬化、提高和改善记忆、抗肿瘤、调节免疫、抗炎、抗病毒等广泛的作用^[33], 但因缺少合适的研究材料, 非淀粉多糖和低聚果糖至今没有成为作物品质改良的热点. 黄精根茎不含淀粉, 富含非淀粉多糖和低聚果糖, 种子含有淀粉(图1D~F), 为淀粉缺失机制、非淀粉多糖和低聚果糖合成机制研究提供了重要材料.

通过种子和根茎比较转录组分析发现, 糖类代谢途径中的显著差异基因主要为蔗糖合酶、果糖激酶、蔗糖转运蛋白及果聚糖合成途径基因(图2), 其中蔗糖合酶基因在根茎中表达量极低, 果聚糖合成途径基因在根茎中均显著上调, 因此本文推测, 黄精根茎中淀粉消失, 是因为蔗糖合酶基因的表达被严重抑制, 导致蔗糖不能正常分解为UDP-葡萄糖和果糖, 从而阻断下游淀粉合成通路的正常运转; 而果聚糖合成通路基因的显著上调则表明, 蔗糖在根茎中转化为果聚糖和低聚果糖(图3), 其存在于约15%的被子植物中, 被认为是植物的第三种糖类贮藏形式, 特别是在菊科、禾

本科、百合科、天门冬科等植物中^[34,35]. 上述结果在转录水平初步揭示了淀粉缺失机制. 后续通过黄精基因组测序、比较基因组分析深入挖掘黄精根茎淀粉缺失和非淀粉多糖的生物合成机制, 明确调控的关键目的基因, 可为未来依托基因转化和基因编辑技术对其他粮食作物进行品质改良提供理论依据和物质基础.

3 黄精林下种植, 开辟粮食安全新路径

大约12000年前人类开始进行作物驯化, 超过2500种植物接受过驯化或半驯化成为食物, 至今仅水稻、小麦和玉米等20种植物提供了人类消耗的90%热量^[1,36-39], 但它们的营养物质主要为淀粉, 不能满足人民群众日益增长的健康需求. 因此, 近年来野生或半野生植物重新被驯化为新的补充作物获得了极大关注^[40,41].

黄精属植物适应性强, 野生资源在北半球温带地区广泛分布^[4]. 2020年版《中国药典》记载的黄精、

图2 多花黄精种子和根茎糖类途径显著差异基因。SUT: 蔗糖转运蛋白; SUS: 蔗糖合酶; FK: 果糖激酶; 1-SST: 蔗糖1-果糖基转移酶; 6G-FFT: 果聚糖6G-果糖基转移酶

Figure 2 Significantly different genes of carbohydrate biosynthetic pathway between seed and rhizome of *P. cyrtoneura*. SUT, sucrose transporter; SUS, sucrose synthase; FK, fructose kinase; 1-SST, sucrose 1-fructosyltransferase; 6G-FFT, 6(G)-fructosyltransferase

图3 多花黄精根茎糖类生物合成途径。SUT: 蔗糖转运蛋白; SUS: 蔗糖合酶; FK: 果糖激酶; 1-FFT: 果聚糖1-果糖基转移酶; 1-SST: 蔗糖1-果糖基转移酶; 6G-FFT: 果聚糖6G-果糖基转移酶

Figure 3 Significantly different genes of carbohydrate biosynthetic pathway between seed and rhizome of *P. cyrtoneura*. SUT, sucrose transporter; SUS, sucrose synthase; FK, fructose kinase; 1-FFT, fructan 1-fructosyltransferase; 1-SST, sucrose 1-fructosyltransferase; 6G-FFT, 6(G)-fructosyltransferase

滇黄精、多花黄精3个药食同源物种,基本涵盖了全国适合人工经营的区域,其中黄精产自黑龙江、吉林、辽宁、河北、山西、陕西、内蒙古、宁夏、甘肃、河南、山东、安徽,海拔180~2800 m处,朝鲜、蒙古和俄罗斯西伯利亚地区也有分布;滇黄精产自广西、贵

州、四川、重庆、云南,海拔700~3600 m处,越南、缅甸、泰国也有分布;多花黄精产自浙江、福建、江西、安徽、湖南、重庆、贵州、湖北、四川、河南、江苏、广东、广西,海拔200~2100 m处。

黄精自然生长于山地林下、灌丛或山坡阴面,森林中郁闭度为0.4~0.6或遮荫60%的透光率条件下生长良好;适合种植在有机质含量丰富、保水和排水性能较好的腐殖质土或沙质壤土中^[42,43],非常适宜林下栽培。多倍化是作物驯化与改良的重要方向,在生物量、耐逆性、抗病虫性和适应性等方面均具有优势^[44,45],黄精存在天然多倍化和非整倍化现象,为倍性育种和高效栽培提供了天然材料^[46,47]。黄精属于多年生草本植物,无需每年播种,生长季节长,具有广泛的抗逆性,可做到一次种植永续采收,符合建立多样化的多年生粮食种植体系的现代理念,是实现农业可持续发展的的重要手段^[48]。黄精林下规范种植,合理经营,每公顷产1500 kg干品;而且黄精根茎可在土中生长和保存多年(图4),不需良田、不占耕地、不争林地、不要仓储,“藏粮于林下”,是“藏粮于地、藏粮于技”的国家战略的深化。我国林地面积为31259万公顷(2017年国家统计局),2000万公顷国家储备林(《国家储备林建设规划(2018~2035年)》)、3588万公顷经济林(其中核桃867万公顷、油茶453万公顷)(《2016年中国国土绿化状况公报》)都非常适合黄精栽培,这将开辟一条保障国家粮食安全、粮食产业转型升级的新路径。如果着眼世界范围,全球许多林地资源均有潜力开发,借助“一带一路”的辐射和推广,“藏粮于林下”的策略可以为全世界,特别是非洲地区,提供解决国际粮食安全的中国方案。

4 黄精产业具备千亿级产业潜力

“药食同源”思想源远流长。《黄帝内经·太素》“空腹食之为食物,患者食之为药物”。《神农本草经》上、中品各120种,其中上品药“无毒,多服、久服不伤人”。2016年,国务院《中医药发展战略规划纲要(2016—2030年)》提出,要发挥中医药“在治未病中的主导作用、在重大疾病治疗中的协同作用、在疾病康复中的核心作用”。2020年的新冠疫情,中医药起到了重要作用,免疫力是最好的医生已经成为共识,强有力地推动了“药食同源”食疗经济结构逐步爆发。

图 4 多花黄精林下种植. A: 杉木林下; B: 松树林下; C: 杂木林下; D: 林下种植多花黄精根茎

Figure 4 *P. cyrtoneura* of in-forest planting. A: In the fir forest; B: in the pine forest; C: in the miscellaneous tree forest; D: rhizome of *P. cyrtoneura* planted in forest

黄精食药同源口感好, 产品多元化, 迎合现代大众健康需求. 当今社会快节奏的生活, 巨大的工作压力, 令许多现代人都处于亚健康状态, 头痛头晕、夜寐不安、心情烦躁、腰酸背痛等阴虚体质、亚健康的越来越多. 黄精作为优质杂粮, 已开发出米饭与稀饭伴侣、代餐粉、面条、九制蜜饯、粉丝、馒头、粽子、饼干、月饼、酒、糖(丸)、饮料; 作为保健品, 已开发出增强免疫力、缓解体力疲劳、辅助降血糖、辅助降血脂、延缓衰老、改善睡眠、辅助改善记忆、增加骨密度、对化学性肝损伤有辅助保护作用、改善营养性贫血、抗氧化等系列保健食品(国家市场监督管理总局特殊食品信息查询平台).

黄精是糖尿病患者、老年人性价比最高的食疗产品之一. 2019年中国糖尿病患者约1.164亿人(全球共有4.63亿), 老年人口总数为1.760亿. 如果20%上述人群每天食用50 g黄精, 年需制黄精106.7万吨(约折干黄精150万吨). 开发黄精抗氧化、抗衰老、保肝、增强免疫功能、改善记忆、补肾、不饥、延年等功效特殊医学用途配方食品, 辅食营养补充品, 运动营养食品, 以及其他具有相应国家标准的特殊膳食用食品和保健

食品潜力也十分巨大. 此外, 黄精除根茎外, 叶、花、实皆可食用, 开发辅粮、菜、茶, 潜力很大^[9,10,49].

黄精林下规模化种植技术基本成熟^[50,51]. 利用现有技术, 林下规范种植每公顷产1500公斤干品, 按现行市场价75元/kg计算, 每公顷年产值11.25万元, 实现山区群众不砍树也能富, 真正实现“绿水青山就是金山银山”. 2015年以来, 黄精在浙江、云南、贵州、湖南、江西、安徽、广西、四川、湖北等省(自治区)快速发展, 一个很重要的原因就是黄精在支撑脱贫致富、乡村振兴中发挥了重要作用. 其中, 贵州省政府提出“环梵净山百亿黄精产业”, 湖南新化县政府提出打造“新化县百亿黄精产业”, 浙江磐安提出打造“磐安县百亿级黄精产业”. 浙江淳安, 湖南安化、新晃、洪江, 重庆秀山、石柱, 江西铜鼓, 四川筠连, 安徽青阳、金寨, 云南普洱、曲靖, 贵州印江、六盘水, 山东泰安, 辽宁抚顺等省市的黄精产业规模也迅速发展, 发展面积均在万亩以上. 如果在10%的储备林、5%的经济林下种植黄精, 可生产黄精569万吨, 种植业产值可达4268亿元. 黄精遗传多样性丰富^[52], 品种改良和高效栽培潜力巨大.

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Polygonati rhizoma—a new high-quality crop with great potential and not occupying farmland

SI JinPing¹ & ZHU YuXian²

1 State Key Laboratory of Subtropical Silviculture, Zhejiang A&F University, Hangzhou 311300, China;

2 Institute for Advanced Studies, Wuhan University, Wuhan 430072, China

Huangjing (Polygonati rhizoma), named after “its absorption of the essence from the earth”, was first recorded in the Chinese pharmaceutical monograph *Sheng Nong's Herbal Classic*; was named after “its absorption of the essence from the earth”. Polygonati rhizoma is a traditional classic dual-purpose plant used in food and medicine and can replace food. Current research shows that Polygonati rhizoma does not contain starch, but is rich in non-starch polysaccharides, fructooligosaccharides, steroids, triterpenoid saponins, flavonoids and other nutritional components. It has the functions of nourishing Qi and Yin, invigorating the spleen, moisturizing the lung and replenishing the kidney. Non-starch polysaccharides and fructooligosaccharides in Polygonati rhizoma not only have similar effects like resistant starch in lowering postprandial blood glucose, but also enhancing immunity and regulating glucose by promoting insulin secretion and improving insulin sensitivity. The plant becomes one of the most cost-effective food therapy products for diabetic patients and the elderly. Polygonati rhizoma is a perennial plant with a long growth period and a wide range of stress resistance. It can be planted once and harvested continuously. The plant conforms to the modern concept, which establishes a perennial diversified food planting system for sustainable agricultural development. The natural polyploidization and aneuploidy of Polygonati rhizome provide study materials for ploidy breeding. The plant is suitable for large-scale cultivation in subtropical, temperate and cold temperate forests. It does not require fertile land, does not need to occupy arable land, does not need to compete with forest, and does not need warehouse storage. Instead, it is a “food storage in the forest”. *Polygonatum* planting is an innovative way to ensure national food security and the transformation as well as upgrading of the food industry. With current technology aid, standard in-forest planting of polygonati rhizoma can produce 1500 kg dry products per hectare. In return, based on the current market price of 75 yuan per kg, the annual output value per hectare is 112,500 yuan. This suggests that people in mountainous areas can become rich without cutting down trees, and accord with the concept that lucid waters and lush mountains are invaluable assets. Suppose Polygonati rhizoma were planted in 10% reserve forests and 5% economic forests. In that case, a total of 5.69 million tons of *Polygonatum* could be produced, the output value of planting industry could reach 426.8 billion yuan. Polygonati rhizoma is rich in genetic diversity and has great potential for germplasm improvement and high-efficiency cultivation. In-depth investigation of the mechanism underlying starch deficiency in its rhizome can provide an important theoretical basis for quality improvement of crops.

Polygonati rhizoma, food, starch, medicinal and edible plant, in-forest planting, perennation, polyploidization, non-starch polysaccharide

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