

果袋颜色对番茄果实微环境及产量和品质的影响*

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摘要 为确定果袋颜色的生态学和生物学效应,以 JYK 番茄为试材,采用不同颜色果袋进行套袋处理,以不套袋为对照,研究了不同颜色果袋内微环境的变化及其对果实生长发育、产量和品质的影响.结果表明:不同颜色果袋均具有降低光强、提高温度、增加湿度的作用,并均可促进番茄果实膨大,增加单果质量,促进果实提早成熟.其中,以黑色果袋增温促长效果最好,其果实成熟期较对照提早 10 d,单果质量增加 27.2%;无色、蓝色及红色果袋处理的果实成熟期分别较对照提早 8、3 和 2 d,单果质量分别增加 11.8%、6.4% 和 4.8%.此外,套袋还可促进果实着色,显著提高番茄红素含量,但所有处理的果实硬度及可溶性固形物、可溶性糖、可溶性蛋白含量均低于对照.表明番茄套袋虽增加了产量,但降低了其营养品质.

关键词 番茄 果实套袋 果袋颜色 产量 品质

文章编号 1001-9332(2013)08-2229-06 **中图分类号** S641.2 **文献标识码** A

Effects of fruit bag color on the microenvironment, yield and quality of tomato fruits. WANG Lei^{1,2}, GAO Fang-sheng³, XU Kun¹, XU Ning¹ (¹ College of Horticulture Science and Engineering, Shandong Agricultural University, Tai'an 271018, Shandong, China; ² Dezhou Academy of Agricultural Sciences, Dezhou 253000, Shandong, China; ³ College of Ecology and Garden Architecture, Dezhou University, Dezhou 253000, Shandong, China). -Chin. J. Appl. Ecol., 2013, 24(8): 2229-2234.

Abstract: In order to clarify the ecological and biological effects of fruit bagging, tomato variety JYK was taken as the test material to study the changes of the microenvironment in different color fruit bags and the effects of these changes on the fruit development, yield and quality, with the treatment without fruit bagging as the control (CK). The results showed that bagging with different color fruit bags had positive effects in decreasing the light intensity of the microenvironment and increasing its temperature and humidity, and thus, increased the single fruit mass and promoted the harvest stage advanced. Black bag had the best effects in increasing microenvironment temperature and fruit mass, with the single fruit mass increased by 27.2% and the harvest period shortened by 10 days, compared with CK. The fruit maturation period in colorless bag, blue bag and red bag was shortened by 8, 3 and 2 days, and the single mass was increased by 11.8%, 6.4% and 4.8%, respectively. Moreover, the coloring and lycopene content of the fruits with different color bags bagging were improved, but the fruit rigidity and fruit soluble solid, soluble protein, and soluble sugar contents were decreased. Therefore, bagging with different color bags could improve the yield of tomato fruits, but decrease the fruit nutritional quality.

Key words: tomato; fruit bagging; fruit bag color; yield; quality.

番茄 (*Lycopersicon esculentum*) 是我国冬春设施栽培面积最大的蔬菜之一,低温弱光不仅影响植株生长发育,阻碍果实着色,延迟果实成熟,还导致病

害较多,用药量较大,极易造成果实农药残留超标,成为制约番茄产量与品质的关键因素^[1],而番茄果实套袋可有效提高冬春季果袋内的温度,改善果实发育微环境,促进果实膨大,提高产量,改善果实外观品质,并显著降低农药残留量^[2-3].王梅等^[4]研究表明,白膜袋和白纸贴膜袋均能提高番茄果实单

* 山东省农业重大应用技术创新项目(2011-139)和山东省现代农业产业技术体系专项(201002-05)资助.

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2012-12-04 收稿,2013-05-31 接受.

果质量,促进果实成熟,改善果实外观品质,但灰膜袋和铝箔袋却降低了果实单果质量.程智慧等^[5]对黄瓜的研究也表明,套袋增加了单瓜质量,降低了大头瓜率,但果实叶绿素和类胡萝卜素含量降低;陈志杰等^[6]也得出了相似的结果.还有研究还表明,蓝光可促进草莓^[7]果实花青苷的合成,而红光则有利于苹果^[8]、梨^[9]、甜椒^[10]等果实花青苷和番茄^[11]果实番茄红素的积累,这与光质可调控色素合成酶的活性和基因表达有关^[12-13].赵英等^[14-15]研究表明,不同颜色果袋内的光质不同,以其对番茄果实套袋后,单果质量虽无显著变化,但果实着色提早,番茄红素含量增加,成熟整齐度高,畸形果率降低,且不同季节不同颜色果袋对番茄品质的影响不同.为进一步探讨不同颜色果袋的生态学与生物学效应,本文研究了深冬季节日光温室番茄套袋后,不同颜色果袋内微生态环境的变化,及其对番茄果实生长发育和品质的影响,旨在为完善日光温室越冬番茄套袋栽培提供理论依据.

1 材料与方法

1.1 试验设计

试验在山东农业大学蔬菜实验站日光温室进行.供试番茄品种为‘JYK’,为无限生长型,抗病,耐低温,果实红色,圆形,单果质量250 g左右,耐贮运.供试果袋长35 cm、宽20 cm,以0.02 mm聚乙烯塑料薄膜自制,按其颜色不同设4个处理,分别为无色(Colorless)、黑色(Black)、红色(Red)、蓝色(Blue),以不套袋为对照(CK).试验设3个重复,随机区组排列,每小区面积24 m²,栽植番茄80株.番茄开花坐果期,选取生长势一致且处于温室中部的植株做好标记,当番茄整穗多数果实横径长至0.5 cm左右时进行疏果,每个果穗均保留4个果实,进行整果穗连续套袋处理,待植株长至4穗果时打顶.

1.2 测定指标和方法

为保证测试结果的一致性,在先前标记的植株中,每小区再选择3株,分别测定第2果穗果袋内微环境及果实生长发育情况.

1.2.1 果袋内微生态环境的测定 番茄果实套袋后,自11月27日始,测定晴天10:00左右果袋内光强、温度及相对湿度,以后每隔20 d测定1次,并于果实快速膨大期(12月25日)测定晴天果袋内微环境日变化,每次测定均重复3次.光照强度用Li-6400照度计测定,温度和相对湿度使用CENTER313型数显式温湿度计进行测定.

1.2.2 果实膨大速率的测定 用游标卡尺于套袋前测量初始横径(D_1),果实绿熟时测量最终横径(D_2)及纵径(H_2),根据膨大天数(t),计算果实膨大速率(r): $r=(D_2-D_1)/t$,并计算果形指数 Fi : $Fi=H_2/D_2$.

1.2.3 果实品质的测定 以果面全部转红为果实成熟标志,按不同处理成熟期分期采收,称取单果质量,并分析其商品品质和营养成分.果实硬度用HG-12果品硬度计测量果实最大横径处;番茄红素用甲苯洗涤法^[16]测定;叶绿素和类胡萝卜素用丙酮提取比色法^[17]进行测定;可溶性糖用蒽酮比色法^[17]测定;可溶性蛋白质用考马斯亮蓝G-250染色比色法^[17]测定;可滴定酸采用滴定法^[18]测定;可溶性固形物用阿贝折射仪^[18]测定;Vc含量用2,6-二氯酚靛酚钠滴定法^[17]测定.

1.3 数据处理

采用DPS软件对数据进行处理,采用LSD法进行差异显著性分析($\alpha=0.05$).

2 结果与分析

2.1 番茄果实膨大期果袋内微生态环境的动态变化

番茄果实膨大期不同颜色果袋内光照、温度及空气相对湿度的变化趋势与对照基本一致,但果袋内光强均显著低于对照,而果袋内温度及相对湿度均显著高于对照.光强以无色果袋内较高,达自然光强的75%左右,蓝色、红色、黑色果袋依次降低,分别达自然光强的65%、55%和10%左右.套袋均可显著提高番茄果实发育的环境温度,其中以黑色果袋内的温度较高,比对照高3.5℃左右,而无色、蓝色和红色果袋分别比对照高2.5、2.0和1.5℃左右.无色、红色和蓝色果袋内的相对湿度差异不大,但均显著高于对照,比对照高20%左右,黑色果袋内的相对湿度尽管比对照高12%左右,但在整个果实发育过程中均显著低于其他果袋(图1).

2.2 不同颜色果袋内微生态环境的日变化特征

由图2可以看出,果袋内光强的日变化随自然光强的变化而变化,且显著影响果袋内温度的日变化,但不同时间各处理温度差异显著,如8:00果袋内温度略高于对照,12:00温度达最高值时,黑色、无色、蓝色和红色果袋内的温度分别达29.3、28.9、27.9和27.0℃,分别比对照高4.6、4.2、3.2和2.3℃,之后,尽管温度降低,但14:00之前,果袋内温度降幅较小,即使至16:00果袋内的温度仍显著高于对照.一天中各颜色果袋内空气相对湿度均显著高

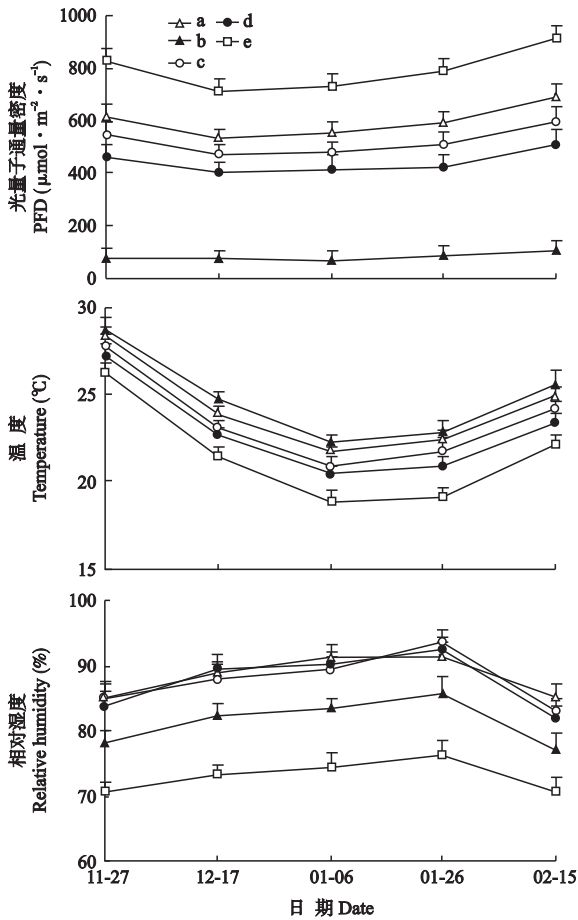


图 1 番茄果实膨大期不同颜色果袋内微环境动态变化

Fig. 1 Dynamic changes of micro-environment in different color bags at tomato fruit inflating stage.

a) 无色 Colorless; b) 黑色 Black; c) 蓝色 Blue; d) 红色 Red; e) 对照 Control (CK). 下同 The same below.

于对照,且除黑色果袋较低外,其他处理之间无显著差异。

2.3 不同颜色果袋对番茄果实色素含量的影响

随着番茄果实的生长,其叶绿素含量逐渐降低,套袋可以加速叶绿素的降解,但不同颜色果袋降低叶绿素含量的程度不同,如在开花后 60 d 时,无色、蓝色、黑色和红色果袋处理的番茄果实叶绿素含量分别比对照降低 3.3%、11.7%、16.7% 和 22.9%;至 120 d 时,除对照果皮仍存在 $0.99 \mu\text{g} \cdot \text{g}^{-1}$ FM 叶绿素外,套袋处理的番茄果实果皮叶绿素含量均降至 0。

番茄果实类胡萝卜素及番茄红素含量均随果实生长逐渐升高,且无论什么颜色果袋处理,均显著提高了番茄果实类胡萝卜素及番茄红素含量,如开花后 120 d 果实成熟时,红色、无色、蓝色和黑色果袋处理的番茄果实类胡萝卜素含量分别比对照高 43.3%、33.3%、21.7%、10.0%,番茄红素含量分别比对照高 44.1%、37.0%、33.6% 和 27.1% (图 3)。

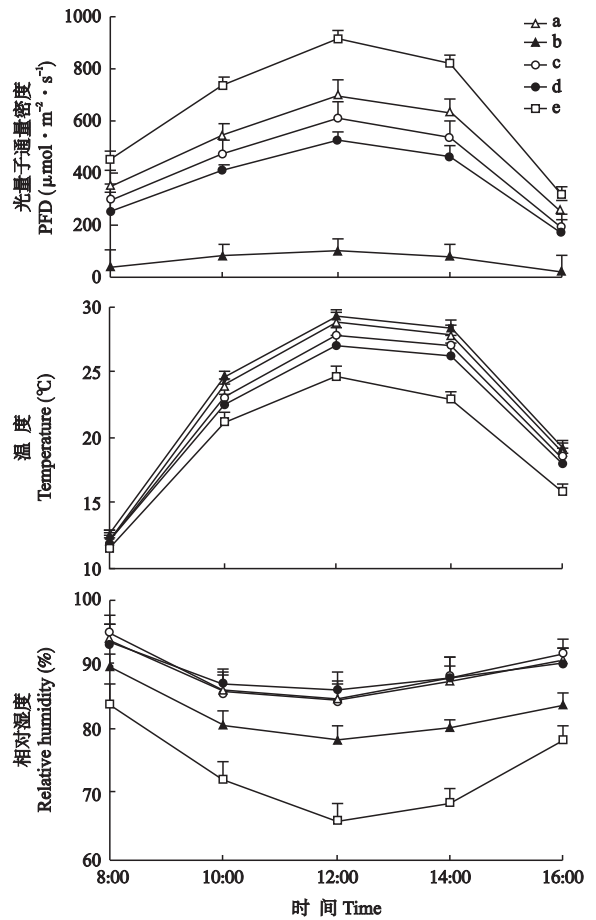


图 2 不同颜色果袋内微环境日变化动态

Fig. 2 Diurnal change of micro-environment in different color bags.

2.4 不同颜色果袋对番茄果实生长速率的影响

由表 1 可以看出,各套袋处理均使番茄果实变大,以黑色果袋效果最好,平均单果质量达 238.4 g,比对照(187.5 g)增加了 27.2%,而红色果袋仅比对照增加 4.8%。可见,不同颜色果袋对番茄果实生长的促进作用存在显著差异。由于不同颜色果袋均改变了果实生长发育的微生态环境,使果实成熟期缩短,如黑色果袋处理的果实成熟期仅 115 d,而无色果袋处理的果实成熟期为 117 d,分别比对照缩短了 10 和 8 d。因此,番茄果实的生长速率以黑色果袋处理最高,达 $0.85 \text{ mm} \cdot \text{d}^{-1}$,显著高于对照($0.63 \text{ mm} \cdot \text{d}^{-1}$)。

2.5 不同颜色果袋对番茄果实品质的影响

由表 2 可以看出,番茄果实套袋处理对果形指数无显著影响,但均显著降低了果实硬度、可溶性糖、可溶性蛋白和可溶性固形物含量,红色和蓝色果袋有利于提高果实维生素 C 和可滴定酸含量,黑色和蓝色果袋处理则相反。此外,除黑色果袋处理果实糖酸比显著高于对照外,其他处理均显著低于对照。

表1 不同颜色果袋对番茄果实生长速率的影响

Table 1 Effects of different color bags on enlarging rate of tomato fruits

果袋 Bag	成熟天数 Days of ripening	初始横径 Initial diameter (cm)	最终横径 Final diameter (cm)	膨大天数 Days of expanding	膨大速率 Growing rate (mm · d ⁻¹)	单果质量 Single fruit mass (g)
红色 Red	123a	0.49a	7.70b	98ab	0.74c	196.4cd
蓝色 Blue	122ab	0.50a	7.73b	97b	0.75c	199.4c
黑色 Black	115c	0.51a	8.15a	90c	0.85a	238.4a
无色 Colorless	117bc	0.49a	7.80ab	92c	0.79b	209.7b
对照 CK	125a	0.50a	6.79c	100a	0.63d	187.5d

不同小写字母表示处理间差异显著($P < 0.05$) Different small letters meant significant difference among treatments at 0.05 level. 下同 The same below.

表2 不同颜色果袋对番茄果实品质的影响

Table 2 Effects of different color bags on fruit quality of tomato

果袋 Bag	果形指数 Fruit shape index	果实硬度 Fruit rigidity (kg · cm ⁻²)	Vc (mg · 100 g ⁻¹)	可溶性糖 Soluble sugar (%)	可溶性蛋白 Soluble protein (mg · g ⁻¹ FM)	可溶性固形物 Soluble solid (%)	可滴定酸 Titratable acid (%)	糖酸比 Sugar-acid rate
红色 Red	0.83a	8.12c	21.72a	6.87c	6.15e	6.67b	0.40b	17.38c
蓝色 Blue	0.84a	8.18c	20.24b	7.31b	7.45d	6.67b	0.42a	17.46c
黑色 Black	0.82a	7.88c	17.79c	7.79a	7.81c	6.07c	0.32e	24.48a
无色 Colorless	0.86a	9.15b	18.49c	7.40b	8.23b	6.50b	0.35d	21.04b
对照 CK	0.85a	10.31a	20.03b	7.97a	9.45a	6.93a	0.37c	21.83b

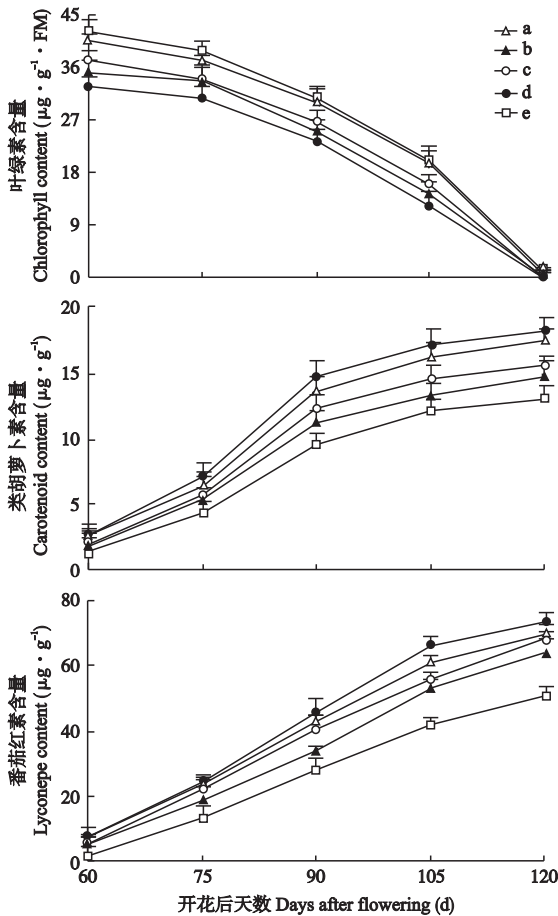


图3 不同颜色果袋对番茄果实果皮色素含量的影响

Fig. 3 Effects of different color bags on pericarp pigment contents of tomato.

3 讨论

番茄果实主要色素形成除受品种遗传特性影响外,与果实发育环境密切相关^[19].叶绿素生物合成过程中,许多酶活性受光影响^[20],而套袋降低了果袋内光照强度,从而影响了叶绿素的合成^[21].研究发现,蓝光可促进风信子愈伤组织叶绿素的形成^[22],增加蓝光比率可提高生姜叶片的叶绿素含量^[23],但蓝膜处理的草莓叶片叶绿素含量低于红膜处理^[24].可见,不同植物叶绿素形成对光质的反应存在差异.本研究表明,套袋可加速番茄果实叶绿素的降解,但以红色、黑色果袋效应大于蓝色及无色果袋.

番茄红素为红果番茄成熟后的主要显色色素^[25],也是类胡萝卜素生物合成的中间产物,其合成过程中的关键酶受温度影响较为显著^[26],因此,温度过高或过低均不利于番茄红素合成.低温是越冬番茄果实成熟及着色缓慢的主要原因,而套袋提高了果实生长发育的微环境温度,因而有利于番茄红素的合成.番茄红素的合成虽然并不要求必要的光照,但一定光照可促进番茄红素合成^[27],这可能是黑色果袋处理番茄果实类胡萝卜素和番茄红素含量较低的原因.红色果袋内果实类胡萝卜素和番茄红素的含量较高,表明番茄红素形成不仅受温度影响,还与透果袋的光质有关. Alba 等^[28]用红光照

射番茄果实后,番茄红素积累增加,这可能与光敏色素影响果实中类胡萝卜素的生物合成有关^[29]。

不同颜色果袋处理不仅影响番茄果实色素含量,还可显著改变果实发育的微环境,从而促进果实膨大,增加单果质量,这与前人研究结果一致^[2,4,6]。果袋颜色不同,透过光强、光质不同,袋内温度也不相同。黑色果袋保温性好,果实膨大速度较高,单果质量较大且成熟较早;其他颜色果袋处理的单果质量虽也显著高于对照,但均低于黑色果袋处理。此外,套袋也显著影响番茄果实品质,但研究结论存在较大差异。赵英等^[14-15]研究表明,春夏季番茄套袋对果实可溶性固形物、可溶性蛋白和维生素 C 含量均无显著影响,但红色膜袋降低了果实可溶性糖含量;秋冬季番茄套袋,除可溶性固形物和可溶性蛋白含量无显著差异外,其可溶性糖含量也未表现差异,但红色膜袋提高了果实维生素 C 含量;而陈志杰等^[30]研究表明,膜袋处理可以提高番茄总糖、维生素 C 及可溶性固形物含量,在黄瓜上进行套袋处理也得到类似结果^[6]。本研究中,所有果袋处理的番茄果实硬度、可溶性蛋白、可溶性固形物、可溶性糖含量均显著低于对照,表明套袋虽增加了番茄果实产量,却降低了番茄果实营养品质。

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