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含砷鸡粪施肥后对青菜和番茄植株中砷富集的影响

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摘　要：利用给鸡饲喂 50 mg·kg^{-1} 和 80 mg·kg^{-1} 洛克沙生得到的鸡粪进行盆栽试验，研究两种含砷鸡粪对青菜和番茄中砷含量、砷富集因子的影响。结果表明，含砷鸡粪施肥后青菜和番茄植株中砷含量均明显提高；青菜砷含量、砷富集因子高于番茄植株，青菜有明显的砷富集作用；番茄植株中砷含量与其生物量呈负相关、未表现出对砷的富集作用。不同种属蔬菜在含砷鸡粪施肥后对砷有不同的摄入，青菜对砷有明显的富集现象，提示青菜在含砷鸡粪施肥后砷水平有较大影响，存在着砷超标风险。

关键词：含砷鸡粪；砷富集；青菜；番茄；洛克沙生

中图分类号：X503.231　　**文献标志码**：A　　**文章编号**：1672-2043(2011)11-2192-05

Effect of As-bearing Chicken Manure on As Accumulation of Pakchoi Cabbage and Tomato Shoots

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Abstract: The pot cultivation experiments were conducted to investigate the As content and As accumulation of chinese pakchoi cabbage and tomato shoots in soils amended with As-bearing chicken manures which were obtained from feeding 50 mg kg^{-1} and 80 mg kg^{-1} roxarsone to chicken respectively. A one-way analysis of variance (ANOVA) was analyzed the data of As content, biomass, As accumulation factor and chicken manure tested. Results showed As content of two vegetables was significantly higher than the control. The As content and As accumulation factor of pakchoi cabbage were significantly higher than that of tomato shoots, which appeared clear As accumulation trend in pakchoi cabbage. The As content of tomato shoots was negatively correlated with its biomass and the As accumulation phenomena was not appeared. A conclusion was that As uptake capability was depended on its vegetable species and pakchoi cabbage appeared clear As accumulation trend in As contaminated soils. It is implied that heavy application of As containing manures should be avoided in produce of vegetable species with high accumulated potential like as pakchoi cabbage for As safety of foods.

Keywords: As-bearing chicken manure; As accumulation; pakchoi cabbage; tomato; roxarsone

砷是公认的致癌元素之一，长期的砷摄入可引起多种疾病[1]。畜禽养殖过程中有机胂饲料添加剂使用带来的砷污染，是我国及世界范围内环境砷污染的来源之一。洛克沙生是动物生产中常用的砷饲料添加剂，以推荐剂量 50 mg·kg^{-1} 使用，在动物粪便中砷的残留量（以干重计）在 1~315.1 mg·kg^{-1} 范围内[2-4]。由于某些饲料生产企业片面追求其促生长作用，常常超剂量使用，则在粪便中的残留量更大。动物粪便中残留的砷 70%~90%为水溶性的[3-5]，因此，动物粪便作为肥料使用后，会影响土壤及地表水中的砷水平，对土壤中生长的农作物中的砷含量也有影响。

畜禽养殖场附近土壤、水体中砷水平明显提高[6]。含砷的动物粪便施肥后，影响到土壤的氨化和硝化作用[7]；土壤中生长的作物中砷的含量也明显提高，如甜薯中砷含量与国家规定的农作物中砷限量（0.05 mg·kg^{-1}）相比增加了 3~6 倍[6,8]，水稻、小白菜、三叶草及紫花苜蓿等作物中的砷水平明显增加[9-10]；Yao 等[11]发现施用含砷的鸡粪和猪粪施肥后，菠菜将土壤中砷从根转移至植株的能力明显大于苋菜，建议在菠菜生长中尽量避免施用砷残留高的粪便。本文利用盆栽试验研究两种不同砷残留水平的鸡粪施肥后，对青菜和番茄植株的生长及砷富集的影响，以期提高集约化养殖方式下畜禽粪便作为有机肥农用对农作物食用安全性，

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及对畜禽粪便农用加强管理必要性的认识。

1 材料与方法

1.1 材料

供试土壤采自扬州大学花园土(0~20 cm),土质为灰潮土,平均含水率为12.24%,土壤的基本性质为pH6.5,有机质19.1 g·kg^{-1},速效氮81.07 mg·kg^{-1},速效磷39.72 mg·kg^{-1},速效钾74.47 mg·kg^{-1},总砷21.2 mg·kg^{-1},水溶性砷为0.535 mg·kg^{-1}。

洛克沙生原料药:浙江康达动物保健品有限公司,纯度≥98.5%。

鸡粪Ⅰ(CM1)和Ⅱ(CM2)分别为饲料中添加50 mg·kg^{-1}和80 mg·kg^{-1}洛克沙生后收集的鸡新鲜粪便;对照鸡粪(CK)为饲料中不添加洛克沙生得到的鸡粪。这3种鸡粪的基本性质见表1。

青菜种子为扬州青,番茄种子为阳光906杂交种,购于扬州种子公司。

AFS-2202a型双道原子荧光分光光度计(北京万拓仪器有限公司)

1.2 方法

1.2.1 盆栽试验

盆栽试验中供试小盆内径40 cm,鸡粪以2%的比例加入土中,保持75%的湿度作用7 d后装盆。每盆装土8 kg,分别播种10粒青菜或番茄,每一处理组10盆,添加水分至土壤田间持水量的75%。于播种后的20~100 d,分别于每盆中采集植株1株,每次10株,洗净晾干后分别称量地上部分重量,折算为每盆10株统计生物量。同时取表层3~4 cm的土样用于土壤中砷含量测定。植株于65 ℃烘干后粉碎用于砷含量测定。以植株中总砷与土壤中可溶性砷含量之比为富集因子。

表1 试验用鸡粪的有关性质

Table 1 Selected properties of the chicken manures used

项目	CM1(50 mg·kg^{-1} roxarsone feed)	CM2(80 mg·kg^{-1} roxarsone feed)	CK
pH①	6.22	6.23	6.22
OM/g·kg^{-1}	621	620	620
Total As/mg·kg^{-1}	34.3	45.2	20.5
Total P/g·kg^{-1}	5.8	5.9	5.8
Total N/g·kg^{-1}	21.0	21.2	21.0
Total K/g·kg^{-1}	8.2	8.2	8.3
Total Cu/mg·kg^{-1}	122.8	125.2	123.6
Total Zn/mg·kg^{-1}	268.5	266.2	268.0
Total Cr/mg·kg^{-1}	19.0	18.5	18.6
Water-soluble As②	11.2	15.1	7.1

①Measured in a 1∶5 manure to water (*w/v*) suspension.

②Measured in a 1∶10 manure to water (*w/v*) suspension.

1.2.2 原子荧光光度法测定砷含量

鸡粪和土壤样品经HNO_3+$HClO_4$消化后,用原子荧光法测定总砷;可溶性砷经(土∶水=1∶10)提取后用原子荧光法测定。植株样品经HNO_3+H_2SO_4消化后,按GB/T 5009.11—2003原子荧光方法测定总砷。GBW 07603对照品原子荧光测定的回收率为90%~99%。

1.3 统计方法

数据处理采用SPSS 12.0软件,数据统计分析采用ANOVA。

2 结果

2.1 青菜与番茄植株的生长

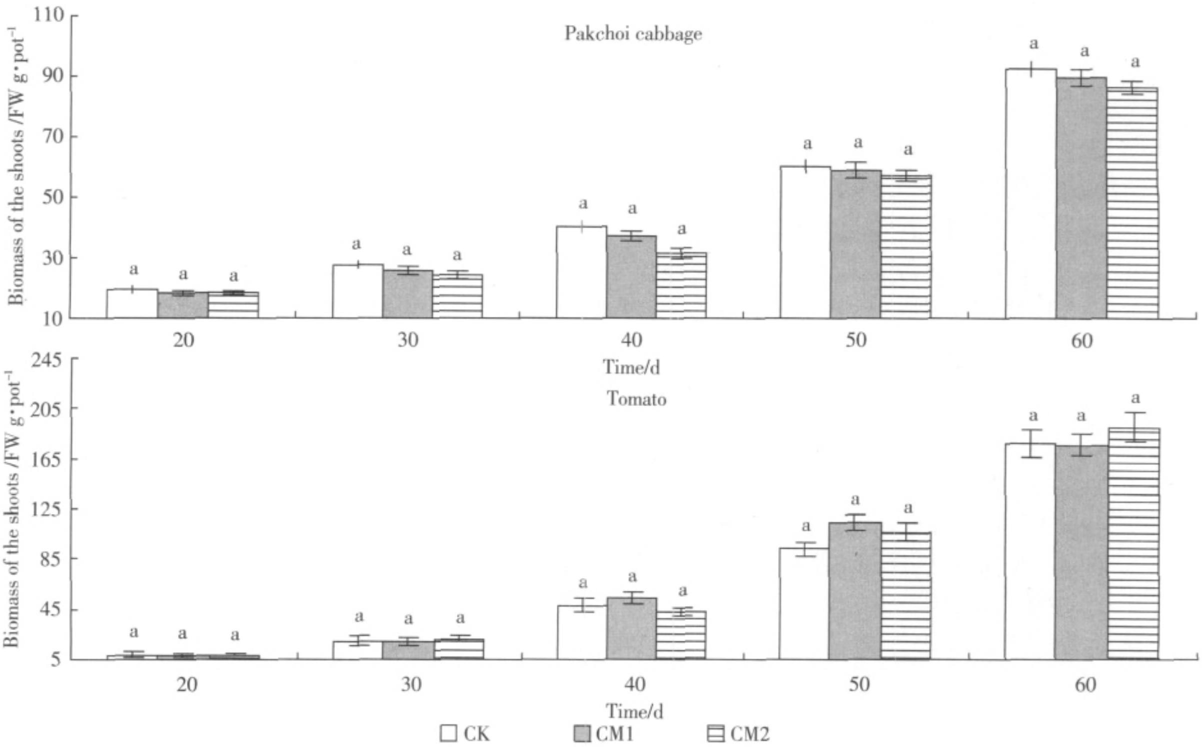
图1为青菜和番茄的生物量。青菜、番茄的生物量及不同粪肥处理后的ANOVA统计分析显示,青菜与番茄植株的生物量有明显差异(P<0.000);但不同粪肥处理与对照组比较,对青菜和番茄的总生物量的影响无显著性差异(P>0.919)。

2.2 青菜与番茄植株中砷含量

图2为试验期内青菜与番茄植株中砷含量变化。试验组青菜随生长时间延长生物量增加,砷含量基本维持在4 mg·kg^{-1}水平,而番茄植株随生长时间延长生物量增加,其砷含量明显降低。两种蔬菜在试验后期的砷含量明显不同,可能的原因有:番茄较大的生物量对砷含量起到了稀释作用;两种蔬菜对土壤中砷有不同的富集能力。经对60 d时两种植株的砷含量与蔬菜品种、施肥处理的ANOVA统计分析可知,青菜中砷含量达4.673 mg·kg^{-1},远高于番茄植株中砷含量1.348 mg·kg^{-1},差异极显著(P<0.000)。鸡粪Ⅰ和Ⅱ施肥后青菜和番茄植株中砷含量均显著高于对照组(P<0.007,P<0.002);鸡粪Ⅰ和Ⅱ施肥处理在青菜生长的前期(30 d前)对青菜砷含量有显著差异,对青菜生长后期及对番茄的砷含量无显著影响(P<0.542)。

2.3 青菜和番茄植株对砷的富集作用

砷富集因子用来评价植物将土壤中砷转移至植株中的能力。图3为青菜和番茄不同生长时间的富集因子。可以明显地看到含砷鸡粪处理后,青菜的砷富集因子随时间的增加而增加,而番茄的砷富集因子基本维持在一个稳定的水平,青菜的富集因子与对照组比较:40 d时为1.6倍,60 d时为4倍,90 d时为6倍。统计表明,青菜和番茄两种蔬菜品种间砷富集因子有明显差异。含砷鸡粪处理与对照组相比,青菜和

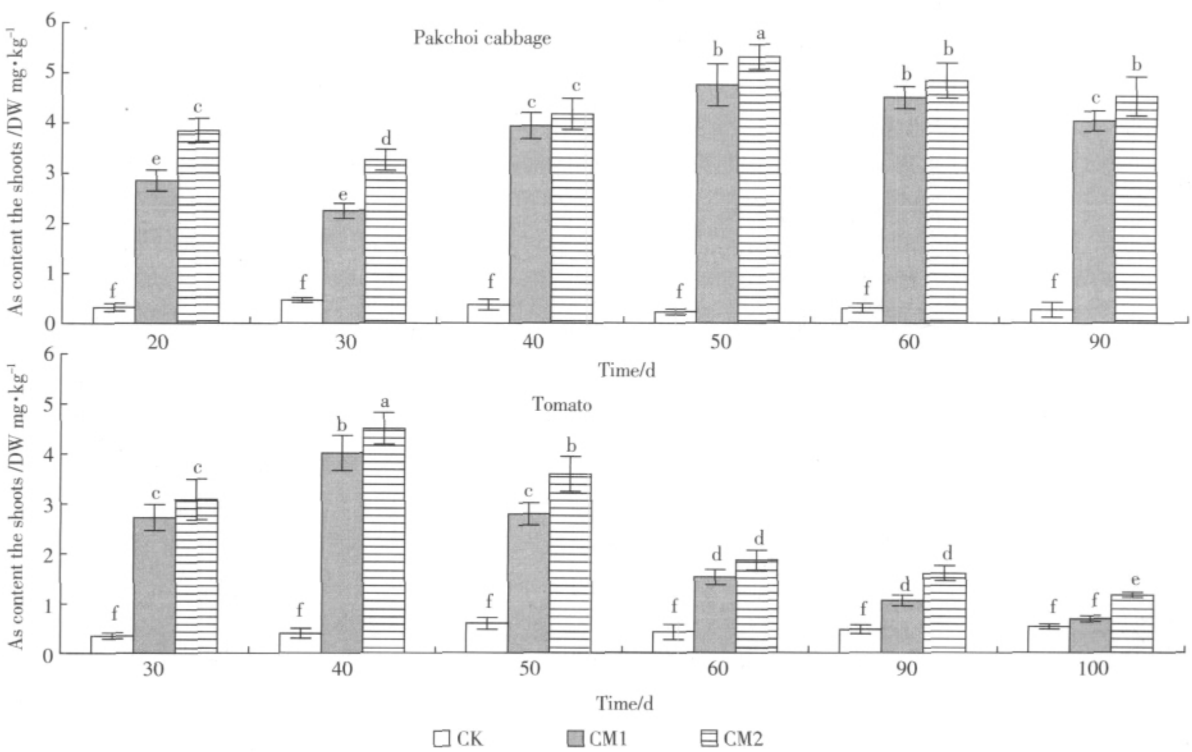


图中相同字母表示同一时间不同处理间差异不显著(P>0.05)

The same letter means there were no significantly difference within CM1/CM2 and CK of two plants at the level of 0.05

图 1 试验鸡粪对青菜和番茄植株生物量的影响

Figure 1 Biomass of the shoots in pakchoi cabbage and tomato in soil as affected by application of chicken manure(CM1 and CM2).



图中不同小写字母表示不同处理的差异显著(P<0.05),下同

Different letters mean significant difference between different treatments(P<0.05). The same below

图 2 试验鸡粪对青菜和番茄植株中砷含量的影响

Figure 2 As contents in the shoots of pakchoi cabbage and tomato as affected by application of chicken manure(CM1 and CM2)in soil

番茄的砷富集因子有明显差异，而不同砷含量的鸡粪处理两组间没有显著差异。

2.4 青菜和番茄植株的生物量与其砷含量的相关性

图4为青菜和番茄植株中砷含量与其生物量的相关性分析。含砷鸡粪施肥后青菜中的砷含量与其生物量呈正相关（r=0.715，P<0.020），而番茄植株中砷含量与其生物量呈负相关（r=−0.836，P<0.003）。因此，番茄植株的生物量对其砷含量确实有稀释作用，青菜的砷富集因子随时间延长的增加与其砷转移能力有关，青菜具有对土壤中砷的富集作用。

3 讨论

不同蔬菜品种显著地影响其生物量、砷含量和砷富集因子[12]。含砷鸡粪施肥后青菜的砷富集因子远大于对照组，且青菜有对土壤中砷的富集趋势，这与文献报道[13-14]芸苔属植物对重金属有较明显地吸收累积现象是相一致的。但本研究中得到的青菜对土壤中砷的富集因子还不能完全反映青菜对土壤中砷的富集作用，因为砷在土壤中存在的形式将在很大程度上影响到砷的生物有效性[15-17]。洛克沙生在粪便中及进入

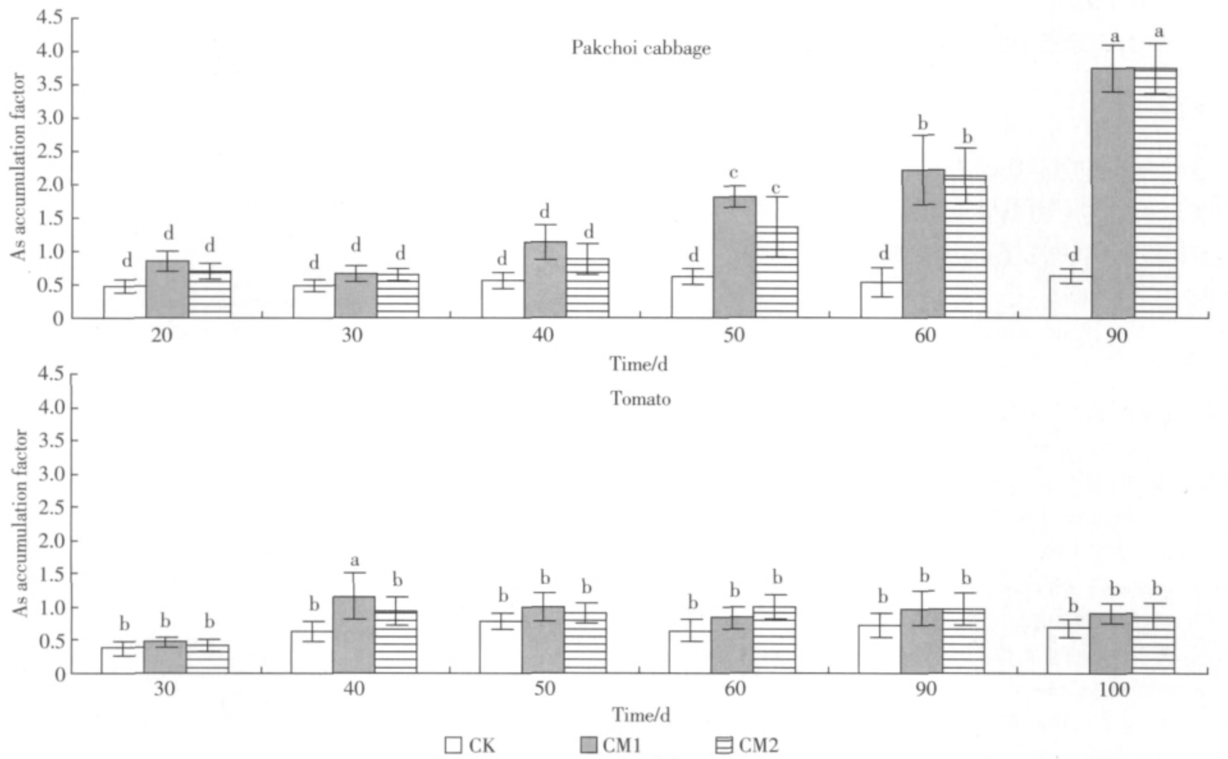


图3 试验鸡粪对青菜和番茄植株As富集因子的影响

Figure 3 As accumulation factor of shoots of pakchoi cabbage and tomato Bars with 'a' letter significantly differ from CK at same harvest time at the level of 0.05

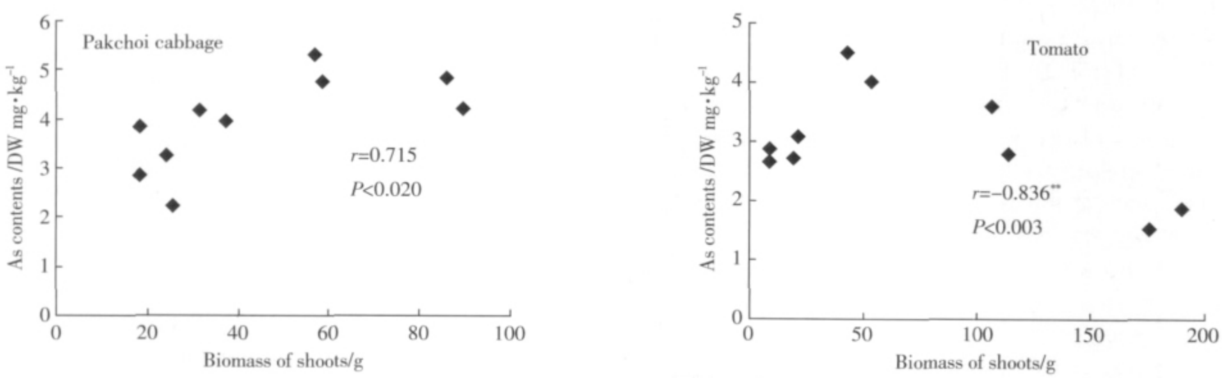


图4 青菜和番茄植株中砷含量与其生物量的相关性

Figure 4 Correlations between As contents and biomass of the shoots of pakchoi cabbage and tomato

环境后,会发生代谢转化为 As(V)、As(III)、甲基胂酸(MMA)、二甲基胂酸(DMA)、苯胂酸化合物及其他砷化合物[18-23]。洛克沙生在新鲜粪便及土壤中的转化受微生物的种类及活性影响较大,但转化的具体途经及比例目前还不详细。且蔬菜对土壤中砷的富集还与施肥的频率、土壤对砷的荷载量及土壤的自我净化能力等其他因素有关。

本试验结果提示含砷的畜禽粪便施肥后对青菜中砷水平有明显的影响,可能会超过我国关于食品中砷的限量,影响到农作物的食用安全性,特别是在设施农业无公害蔬菜生产中多使用有机肥的情况下影响更大,应对畜禽粪便农用的安全性加强管理。

4 结论

含砷鸡粪施肥后影响青菜和番茄植株中砷水平;青菜中砷含量与其生物量呈正相关,而番茄植株中砷含量与其生物量呈负相关;青菜比番茄植株有着明显的砷富集倾向。

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