多功能秸秆纤维基可视化智能标签的构筑和性能表征

刘若婷[1] 宁语苹[1] 任子豪[1] 许士玉[1] 程倩[1] 杨冬梅[1] 王立娟[1*]

（1. 东北林业大学　哈尔滨 150000）

摘　要：智能标签可以实时提供食品新鲜度信息。然而，现有研究的智能标签 pH 响应范围窄，只能监控单一食品的质量，阻碍了其实际应用。为了突破这个瓶颈问题，本研究设计了一种响应范围宽、指示精度高、高效抑菌的纤维素基智能标签用于监控猪肉、牛奶、菠菜的新鲜度。利用草酸改性秸秆纤维素纤维引入羧基基团（-COO⁻），通过静电作用键合带正电荷的壳聚糖季胺盐，进一步吸附阴离子复合染料-甲基红和溴百里香酚蓝，最后自组装成智能标签。壳聚糖季胺盐的引入有效地改善了标签的拉伸强度和断裂伸长率，两者分别增加了 282% 和 16.2%；同时赋予了其优良的抑菌性能，对金黄色葡萄球菌的抑菌率高达100%。在 pH 范围为 3~9 时，该标签呈现了截然不同的高饱和度颜色；遇乙酸蒸汽由绿色转变为粉色，遇氨气又迅速地变回绿色，表明了该智能标签具有快速的酸-碱气体响应性及可逆性。将标签应用于监测猪肉、牛奶以及菠菜的新鲜度，标签从绿色逐渐转变为橘黄色，表明牛奶/菠菜质量状态由新鲜转变为濒临腐败；由绿色转变为黄色，再继续变为浅绿色表明了猪肉质量状态由新鲜到可接受再到濒临腐败的过程。本研究提供了一种可有效地将废弃稻草秸秆纤维高值化转变为多应用范围智能标签的途径，符合节约型社会及国家经济可持续发展理念。

关键词：智能纤维素纤维标签；复合染料；高辨识度；宽响应范围；食品新鲜度

An antibacterial and intelligent cellulose-based label self-assembled via electrovalent bonds for a multi-range sensing of food freshness

Abstract: Intelligent labels provide customers with food freshness information. However, the existing label response is limited and can only detect a single kind of food. Here, an intelligent cellulose-based label with highly antibacterial activity for a multi-range sensing freshness was developed to overcome the limitation. Cellulose fibers were modified using oxalic acid to graft -COO⁻ followed by binding chitosan quaternary ammonium salt (CQAS), the remaining charges of which attached methylene red and bromothymol blue to form response fibers and to further self-assemble into the intelligent label. CQAS electrostatically gathered the dispersed fibers, resulting in an increase in TS and EB of 282% and 16.2%, respectively. After that, the rest positive charges fixed the anionic dyes to broaden pH response range of 3–9 effectively. More significantly, the intelligent label exhibited highly antimicrobial activity, killing 100% of staphylococcus aureus. The rapid acid-base response revealed the potential for practical application in which the label color from green to orange represented the milk or spinach from fresh to close to spoiled, and from green to yellow, and to light green indicated the pork fresh, acceptable, and close to spoiled. This study paves a way for the preparation of intelligent labels in large-scale and promote the commercial application to improve food safety.

Key words: Intelligent cellulose-based label; Multi–range sensing; Food freshness.